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Vaughn W. Russom

NUMBER 1

BULLETIN
OF THE
AMERICAN ASSOCIATION
OF
PETROLEUM GEOLOGISTS

RAYMOND C. MOORE,
Editor

JANUARY-FEBRUARY, 1922

LAWRENCE, KANSAS

Vaughn W. Russom

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RAYMOND C. MOORE
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CONTENTS

Differentiation and Structure of the Glenn Formation.....	5
By W. L. Goldston, Jr.	
Oil Geology of Warren County, Kentucky.....	24
By Stuart St. Clair	
Topographic Criteria of Oil Field Structure.....	37
By V. E. Monett	
The Oil Supply of the United States.....	42
By U. S. Geological Survey	
DISCUSSION	47
On the Stratigraphy of Northeastern Arizona, <i>Raymond C. Moore.</i>	
GEOLOGICAL NOTES	50
Notes to Inventor Geologists, <i>W. E. Dodge</i> ; Haynesville Field, Louisiana, <i>L. P. Teas</i> ; Age of the Producing Sand, ElDorado Field, Arkansas, <i>U. S. Geological Survey</i> ; Occurrence of Limestone in Northeastern Garvin County, Oklahoma, <i>Harve Loomis.</i>	
REVIEWS AND NEW PUBLICATIONS	56
Oil Land Development and Valuation, by <i>R. P. McLaughlin, H. B. Goodrich</i> ; Oil and Gas Prospects in the Vicinity of Buttonwillow, Kern County, California, by <i>R. M. Ferguson, K. C. Heald</i> ; Salt Domes of Northeastern Texas, by <i>Chas. A. Cheney, K. C. Heald</i> ; Lower California; Isthmus of Tehuantepec.	
AT HOME AND ABROAD	61
Current News and Personal Items of the Profession.	

BULLETIN
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**DIFFERENTIATION AND STRUCTURE OF THE GLENN
FORMATION**

BY W. L. GOLDSTON, JR.

INTRODUCTION

The Glenn formation is the connecting exposure between the Pennsylvanian rocks in southeastern Oklahoma and sediments of the same age in north central Texas. The purpose of this paper is to describe the stratigraphy and structure of the Glenn and at the same time to offer a basis for correlating the Carboniferous deposits in southern Oklahoma with those of north central Texas. The economic importance of the Glenn formation is briefly pointed out.

A detailed survey of the Glenn formation was made during the summer of 1919. The writer was assisted in the field work by C. J. Wohlford, and by D. K. Greger, who made a collection and classification of the fauna of the Glenn. The author is also indebted to A. W. McCoy and Geo. E. Burton, under whose direction this work was conducted for the Empire Gas and Fuel Company and to Dr. L. C. Snider, for assistance and co-operation in the work. Especial appreciation is extended G. E. Moser and to the Drafting Department of the Oklahoma Geological Survey for maps and cross sections.

LOCATION

The Glenn formation is the name which has been given to the Pennsylvanian deposits in Oklahoma south of the Arbuckle

Mountains. The area of outcrop occurs in the southern thirds of Carter County and in a small portion of the central part of Love County. The area is irregular in shape covering approximately 175 square miles including a part of T. 2 S., R. 1 E.; T. 3 S., R. 1 W., and parts of Ts. 3, 4, 5 S., Rs. 1 and 2 E. Ardmore, the county seat of Love County, is the principal town of this region.

TOPOGRAPHY

The surface elevations in the area of Glenn outcrops range from 900 feet near the hills to 700 feet in the extreme eastern portion. The country lies in the Sandstone Hills region in which the surface is made up of numerous sandstone ridges and a few limestone ridges separated by broad shale valleys. The general trend is in a northwest-southeast direction. Generally the topography follows the shale valleys. The principal streams are the Red and Hickory creeks. The stratigraphy and structure have a marked influence on the topography of this area.

GEOLOGY

The areal geology of this region is shown in Plate I. The Glenn exposure lies essentially between two major uplifts, the Arbuckle Mountains on the north and the Criner Hills on the south. These uplifts are composed of rocks ranging in age from Pre-Cambrian to Mississippian, as follows: Tishomingo granite (Pre-Camb.), Reagan sandstone (Camb.), Arbuckle limestone (Camb.-Ord.), Simpson formation (Ord.), Woodford limestone (Ord.), Hunton limestone (Sil.-Dev.), Woodford chert (Dev.-Miss.), and Sycamore limestone (Miss.). Caney shales, representing the upper sediments of the Mississippian series are about 1,600 feet thick and where they form a valley about one-half mile wide at the base of the uplifts.

The Glenn formation lies directly above the Caney shales. The strata of the Glenn have been strongly folded. They consist of 15,000 to 19,000 feet of shales, sandstone, limestone and conglomerates which stand practically on edge. On the east, south and southwest these rocks disappear beneath the Cretaceous sands of the Trinity formation. On the north

the overlapping deposits of Redbeds rest unconformably upon the up-turned edges of the Pennsylvanian strata.

STRATIGRAPHY

The Glenn formation apparently lies conformably upon the Caney shales, the two series having been separated largely upon the basis of lithology. The Caney shales are black, very hard, and slaty. The basal shales of the Glenn are black but much softer in character. A few Pennsylvanian cephalopods were found in the Santa Fe railroad cut north of Berwyn in a sandstone occurring about 400 feet above the base of the Glenn.

In Plate II are four vertical sections of the Glenn sediments. Section *A* totals 13,000 feet and was measured from the Arbuckle Mountains to the basin of the Ardmore Syncline. Section *C* was measured from the base of the syncline to the Criner Hills, and has a thickness of 12,000 feet. Toward the south and east, additional deposits form the upper part of the Glenn. The maximum thickness of these sediments is shown in section *D*. This section was measured southeast of the Criner Hills and has a thickness of 19,000 feet.

The Glenn has been divided into five members. Beginning with the basal member, these are here named the Springer, Otterville, Cup Coral, Deese, and Hoxbar members.

SPRINGER MEMBER

The Springer member includes the basal part of the Glenn formation, consisting of four to six thousand feet of sediments and covering practically one-half of the area included in the Pennsylvanian exposure. The outcrops of this member border the Arbuckle Mountains and project southward into a peninsular shaped area, the south end of which is three miles north of Ardmore. It also occurs around the Criner Hills covering a zone of about one and one-half miles in width.

The sediments of the Springer consists largely of black and blue shales separated by thin beds of sandstone and limestone. At the base, black is the characteristic color of the shales. Near the top, blue predominates, though even here, there are zones of black shales several feet thick. North of Ardmore,

this formation has no calcareous members. There are twelve brownish or drab sandstones ranging from a few feet to over one hundred feet in thickness. Some of these sandstones grade into shales toward the south and east. Around the Criner Hills, sandstones are less important and numerous beds of thin brownish limestones occur in these deposits.

South of Woodford and on the east side of the Criner Hills, asphalt deposits occur in the upper beds of this member.

OTTERVILLE LIMESTONE MEMBER

The Otterville limestone member forms a low ridge which runs southeast from Otterville. One mile east of the Ardmore Country Club, it runs northward and parallels the mountains again east of Springer. This member also surrounds the town of Glenn, extending as far west as Henry House Creek. South of Ardmore it runs southeastward paralleling the Springer member east of the Criner Hills.

The Otterville limestone is characterized by its oolitic texture. It consists of about 70 feet of solid brown limestone which grades locally into several beds of brown limestone separated by blue shales.

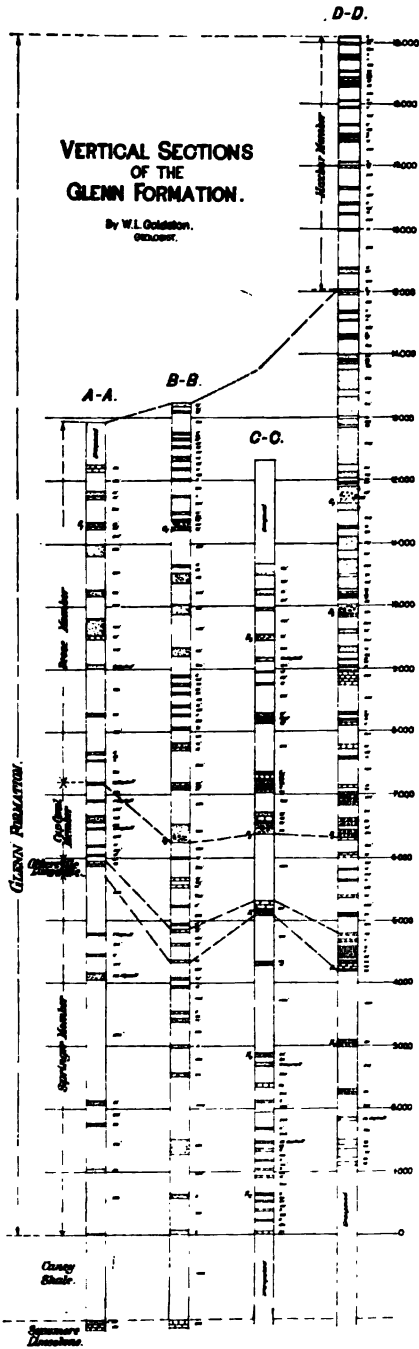
CUP CORAL MEMBER

The Cup Coral member parallels the Otterville limestone. It is composed of 1,500 to 1,800 feet of sediment which covers a zone ranging from one-third to three-fourths of a mile in width. These sediments consist of blue shales separated by thin sandstones and an occasional limestone. The member is easily distinguished by a white limestone near the top which carries a large cup coral, *Campophyllum torquium*. South of Ardmore this limestone is found exposed in only one place. In this area the top of the member is more easily distinguished by a thick conglomerate which forms the basal deposits of the Deese member.

South of Woodford, five of the seven sandstone beds of this member are asphalt bearing.

DEESE MEMBER

The Deese member lies in a northwest-southeast exposure just east of Deese. Its outcrops parallel those of other parts of the Glenn, and north of Ardmore they extend as far east as



the Santa Fe Railway. The basal part of this member is exposed in a small area immediately west of Glenn. It also occurs east of the Criner Hills, along a northwest-southeast zone which ranges in width from one and one-half miles, west of Ardmore, to three miles east of Overbrook.

This member produces the roughest topography in the region. Its sediments, with a total thickness of 6,000 to 8,000 feet, are characterized by a large number of massive sandstones, conglomerates, shales, and a few limestones. North of Ardmore the base of this member is marked by a brown limestone bearing an abundance of *Spirifer condor*¹. South of Ardmore this (*Spirifer condor*) horizon is represented by a bed of chert.

HOXBAR MEMBER

The Hoxbar member lies southeast of Ardmore and west of Hoxbar. It is composed of 4,000 feet of the uppermost sediments in the Glenn formation. The basal sediments are characterized by several brown limestones, one of which is prolific *Fusilina cylindrica* horizon. The upper part of the member is characterized by white sandstones which are separated by light blue to yellow and red shales. This member becomes less calcareous toward the southeast. Limestones grade into shales and shales into sandstones and conglomerates.

Near the top of the member, four miles southeast of Ardmore, a coal seam, two to four feet thick, occurs in these sediments.

FAUNA OF THE GLENN FORMATION

Fossils are not abundant in the sediments of the Glenn. The Otterville limestone and Cup Coral members contain the most prolific horizons. Below is the list of the fossils collected and identified by D. K. Greger.

Springer Member

Erisocrinus typus	Pustula punctata
Rhombopora lepidodendroides	Goniatile sp.
Spirifer cameratus	Myalina subquadrata
Squamularia perplexa	Archaeocidaris magastylus
Composita argentea	

¹MSS. species of D. K. Greger.

Otterville Limestone Member

<i>Axophyllum rude</i>	<i>Spirifer cameratus</i>
<i>Michelinia eugeneae</i>	
	<i>Spirifer boonensis</i>
<i>Fenistella</i> sp.	<i>Marginifera wabashensis</i>
<i>Rhombopora lepidodendroides</i>	<i>Squamularia perplexa</i>
	<i>Spiriferina kentuckiensis</i>
<i>Hustedia mormoni</i>	
<i>Productus cora</i>	<i>Chaetetes milleporaceus</i>
<i>Productus semireticulatus</i>	<i>Leda bellistriata</i>
<i>Productus punctatus</i>	Abundant unidentified gastro-
<i>Composita argentea</i>	pods, pelecypods, cephalopods.

Cup Coral Member

<i>Campophyllum torquium</i>	<i>Chonetes granulifer</i>
<i>Axophyllum rude</i>	<i>Productus semireticulatus</i>
	<i>Meekospira peracuta</i>
<i>Fenestella</i> sp.	<i>Ambocoelia planoconvexa</i>
	<i>Hustedia mormoni</i>
<i>Composita argentea</i>	<i>Dielasma bovidens</i>
<i>Squamularia perplexa</i>	
<i>Marginifera wabashensis</i>	<i>Nucula bellistriata</i>
<i>Spirifer boonensis</i>	<i>Nucula concentrica</i>
<i>Spirifer cameratus</i>	<i>Astartella concentrica</i>
<i>Productus semireticulatus</i>	
<i>Productus costatus</i>	<i>Bellerophon crassus</i>
<i>Pustula symmetrica</i>	<i>Flatyceras</i> sp.
<i>Pustula punctata</i>	
<i>Hustedia mormoni</i>	<i>Coloerus</i> sp.
	<i>Orthotetes crassus</i>
<i>Spiriferina kentuckiensis</i>	<i>Euconospira turbiniformis</i>
<i>Chonetes mesolobus</i>	

Deese Member

<i>Rhombopora lepidodendroides</i>	<i>Pustula punctata</i>
<i>Stenopora carbonaria</i>	<i>Spiriferina kentuckiensis</i>
	<i>Squamularia perplexa</i>
<i>Spirifer condor</i>	<i>Marginifera wabashensis</i>
<i>Spirifer cameratus</i>	
<i>Chonetes verneuillianus</i>	<i>Myalina subquadrata</i>
<i>Composita argentea</i>	
<i>Productus semireticulatus</i>	<i>Pleurophorus subcostatus</i>
<i>Productus cora</i>	

Hoxbar Member

<i>Fusulina cylindrica</i>	<i>Composita argentea</i>
	<i>Spirifer cameratus</i>
<i>Productus semireticulatus</i>	
<i>Productus cora</i>	<i>Bellerophon sublaevis</i>

CORRELATION

North of the Arbuckle Mountains all of the Pennsylvanian deposits below the Seminole conglomerates are correlated with the Glenn formation. This correlation is based upon the following structural relations. The so-called Franks conglomerate at Sulphur rests unconformably upon the upturned edges of the older rock. Folding in the latter rocks conform to that in the Glenn formation. The conglomerate at Sulphur represents the deposits from a sea which came after Glenn times. According to work by E. A. Beauman, this conglomerate and the Seminole conglomerate, are the same formation. At the base of the Seminole conglomerate the angular unconformity is an evidence that the period of mountain building movement, which affected the position of the Glenn sediments, also affected the position of the sediments immediately below the Seminole. These sediments are not so strongly folded as those of the Glenn, but the unconformity at the base of the Seminole is pronounced and is known to exist as far north as Okfuskee County.

In north-central Texas the Bend, Millsap, and Canyon formations are the probable equivalents of the Glenn sediments. At the beginning of Cisco times, the members of the Canyon formation were overlain with a group of coarse sediments occurring in the basal part of the Cisco formation. A corresponding change in sedimentation is found immediately above the Glenn.

According to V. V. Waite of the Atlantic Petroleum Company, a fossil representing Cisco times, was found in a well in the Loco field. As the producing sand in the Loco field rests unconformably upon the Arbuckle limestone, these sediments are post-Glenn.

Charles Schuchert, while visiting this area, was inclined to place the fossil bearing sandstone near the base of the Springer member as the equivalent of the Wapanucka limestone. Based on this and the evidence furnished by V. V. Waite and correlating the conglomerate occurring at the base of the Deese member with those in the Thurman sandstone, the following tentative correlation table is presented.

CORRELATION TABLE

North Central Texas	Oklahoma South of Arbuckle Mtns.	Oklahoma North of Arbuckle Mtns.
Canyon formation	GLENN FORMATION Hoxbar member	Holdenville shale Wewoka formation Wetumka shale Calvin sandstone
Strawn formation	Deese member	Sonora formation Stuart shale Thurman sandstone
Millsap formation	Cup Coral member Otterville limestone	Boggy shale Savanna sandstone McAlester shale
Smithwick shales Marble Falls limestone	Springer member	Hartshorne sandst'ne Atoka formation Wapanucka limest'ne
Lower Bend shale	Caney shales	Caney shale

CONFORMITY OF THE GLENN WITH THE OLDER ROCK

It has generally been thought that an angular unconformity exists at the base of the Glenn formation. This conception is probably in part due to the following statements by J. A. Taff*:

The Carboniferous rock as on the northeast side of this anticline has suffered folding, and near the contact with the older rocks are generally steeply inclined and dip toward the northeast. East of the Hickory Creek dips of Carboniferous rocks at and near the contact vary from 25 degrees to 40 degrees, while the older rocks dip at greater angles and in places in different or opposite directions, indicating a great unconformity. Immediately east of the road at its crossing of Hickory Creek, near the west side of sec. 35, T. 5 S., R. 2 E., the contact is evidently upon a fault. At this place the Simpson formation dips toward the southeast while the dip of the Carboniferous is 40 degrees in the oppo-

*Prof. Paper, U. S. Geological Survey, No. 31, 1904, pp. 50.

AREMORE SPACELINE.
SE. →
Orthocentrus Overlap.



site direction. Farther southeast and in the opposite side of the axis of the fold, the Viola, Sylvan, and Hunton formations dip northeast, in the same direction as, but at higher angles, than do the overlying Carboniferous strata. West of Hickory Creek, at the base of the Coal Measures deposits, is a strong unconformity which is probably in part due to faulting. The beds near the base are variable in character along this contact. In some places they appear to be chiefly shale, while in others, especially in secs. 22 and 27, are coarse limestone conglomerates consisting of pebbles of the same nature as the limestones of the Criner Hills.

The occurrence in the Glenn sediment of limestone pebbles of a similar nature to the rocks of the Criner Hills and Arbuckle Mountains is no proof of an angular unconformity at the base of the Glenn. During Glenn times, land masses, composed of similar material from which these pebbles may have come existed east of this area. The Sabine Uplift and Ouachita Mountains are evidences of such uplifts.

In each locality mentioned by Taff, the apparent unconformity between the Coal Measures and older rocks may be due entirely to faulting. The Criner Hills are so intensely faulted that it is almost impossible to determine the true relation between the Glenn formation and the older sediments in this area. The south side of the Arbuckle Mountains offers a much better opportunity for studying this relation. In this region the strike of the basal beds of the Springer member parallels the strike of the Caney shales and Sycamore limestones. The dip of the younger rocks is in the same direction as that of the older. With few exceptions the angle of dip in the basal sediments of the Glenn are equal to and in most places is greater than that in the Mississippian deposits. But since an actual exposure of the Glenn in contact with the Caney shales was not found, no proof of a conformity or an unconformity can be given. The observations as near the contact as exposures were found in this area however, lead the writer to conclude that the Glenn rests conformably upon the Caney shales.

STRUCTURE

In Plate III is a structural map with cross sections of this area. The region is characterized by five steep folds: the Criner Hill Uplift, the Ardmore Syncline, the Caddo Anticline,

the Glenn Syncline, and the Berwyn Anticline. With the exception of the area west of the Criner Hills these folds become less intense toward the south and east. The dip of the rock varies from 90 degrees near Woodford to 5 degrees at Berwyn, and from 65 degrees on the east side of the Criner Hills to 20 degrees west of Hoxbar. West of the Criner Hills, the dip flattens toward the west.

CRINER HILLS UPLIFT

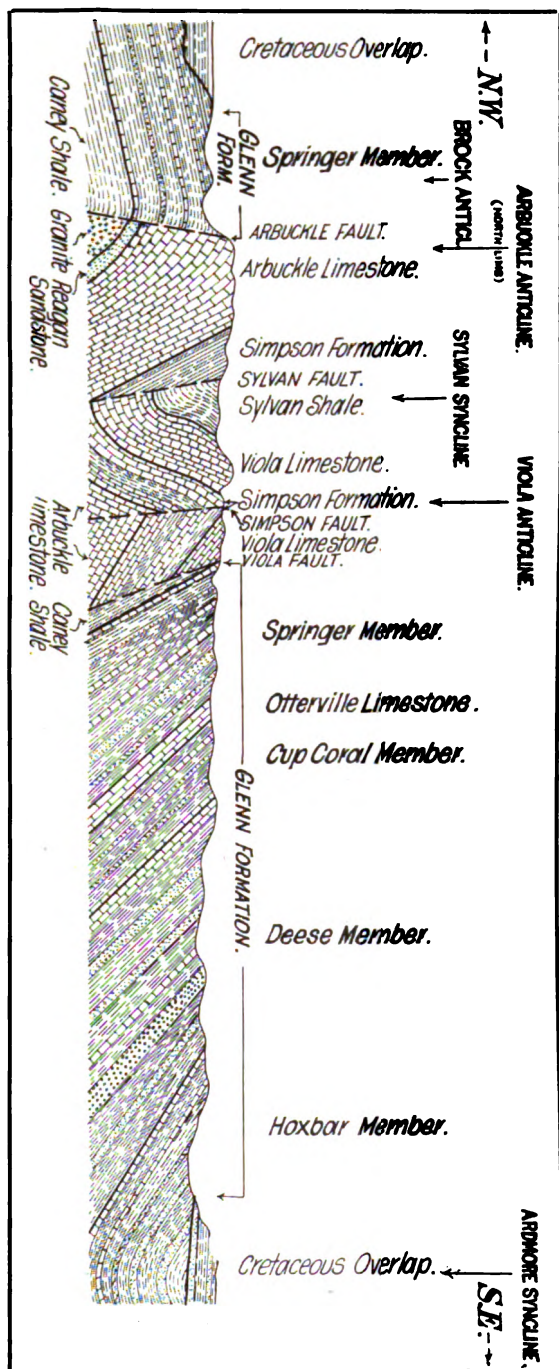
The Criner Hills Uplift is located about 5 miles southwest of Ardmore. The structure of the Glenn sediments around the uplift can be best understood by first pointing out briefly the principal structural features of the older rocks.

The Criner Hills consist of a number of parallel northwest-southeast ridges separated by narrow valleys. Arbuckle limestone, Viola limestone, Hunton limestone, and Sycamore limestone form the ridges. Simpson formation, Sylvan shale, and Woodford chert form the valleys.

Structurally the Criner Hills consist of remnants of three folds. The Arbuckle anticline forms the northwestern portion. The Viola anticline includes the southeastern part and the Sylvan syncline forms the central and southwestern part of the hills. The uplift is bounded on the west by a fault. This fault obliterates the south limb of the Arbuckle anticline and has a throw of sufficient displacement to bring the basal sediments of the Glenn formation in contact with the Arbuckle limestone. On Hickory Creek this fault is intersected by the Sylvan fault which runs northeastward across the Sylvan syncline. The Viola anticline is cut by the Simpson fault which almost parallels the axis of this fold. A fourth fault, exists on the east exposure of the Viola limestone. With the exception of two small areas these three faults limit the hills on the east.

The sediments of the Glenn surround this intensely folded and faulted area of pre-Pennsylvanian rock. On the north and west sides the basal part of the Springer is exposed. On the east side the whole section from Springer to Hoxbar members are exposed. These sediments assume the shape of an anticlinorium which has been intensely faulted on the west

Plate IV. Cross-section A. N.W. S.E. The Criner Hills and the Glenn Formation surrounding these Hills.



side and overturned in places on the east side. This anticlinorium is made up of three principal parts, the Brock anticline on the west, overturned folds on the east, and the central or major fold. The major fold rises in sec. 5, T. 5 S., R. 1 E., and extends southeastward about the axis of the hill. The south limit is buried beneath the Cretaceous overlap and is undefined. On the east side the dip of the rock varies from 55 to 70 degrees; on the north side from 25 to 50 degrees; on the west side from 10 to 20 degrees. The rocks generally are infolded with the older sediments. With the exception of faulted areas and on overturned folds, they dip in the same direction but not always at the same angle.

The Brock anticline parallels the Criner Hills. Its axis crosses secs. 17, 20, 21, 28, and 34, T. 5 S., R. 1 E. The Arbuckle fault which limits the Criner Hills on the west, cuts the northeast flank of this fold about one-half mile east of its crest. There are also a number of cross faults cutting this fold. The exact location and courses of these faults were not determined. The sediments forming the Brock anticline belong to the lower part of the Springer member. On the east side the rock dips at an angle of about 25 degrees, on the west side from 20 to 15 degrees, flattening towards the west.

On the east side of the Criner Hills Uplift are several overturned folds. In the southwest quarter of sec. 36, T. 5 S., R. 2 E., and the northeast quarter of sec. 1, T. 6 S., R. 2 E., the basal part of the Glenn is overturned. The best example of this kind of folding is found in the southwest quarter of sec. 14, T. 5 S., R. 1 E. A cross section of this fold is given. (Figure 1).

ARDMORE SYNCLINE

The Ardmore syncline lies between the Criner Hills and the Caddo anticline. Permian and Cretaceous sediments fill the bottom of this basin. The approximate location of its axis extends through Ardmore crossing secs. 8, 16, 22, 23, and 36, T. 4 S., R. 1 E.; sec. 31, T. 4 S., R. 2 E., and secs. 5, 9, 10, and 14, T. 5 S., R. 2 E. The sediments exposed on the side belong to the Deese and Hoxbar members. The northwest end of the basin is narrow and steep, the rock dipping 55 degrees and 70 degrees on the north and south sides respectively. The trough

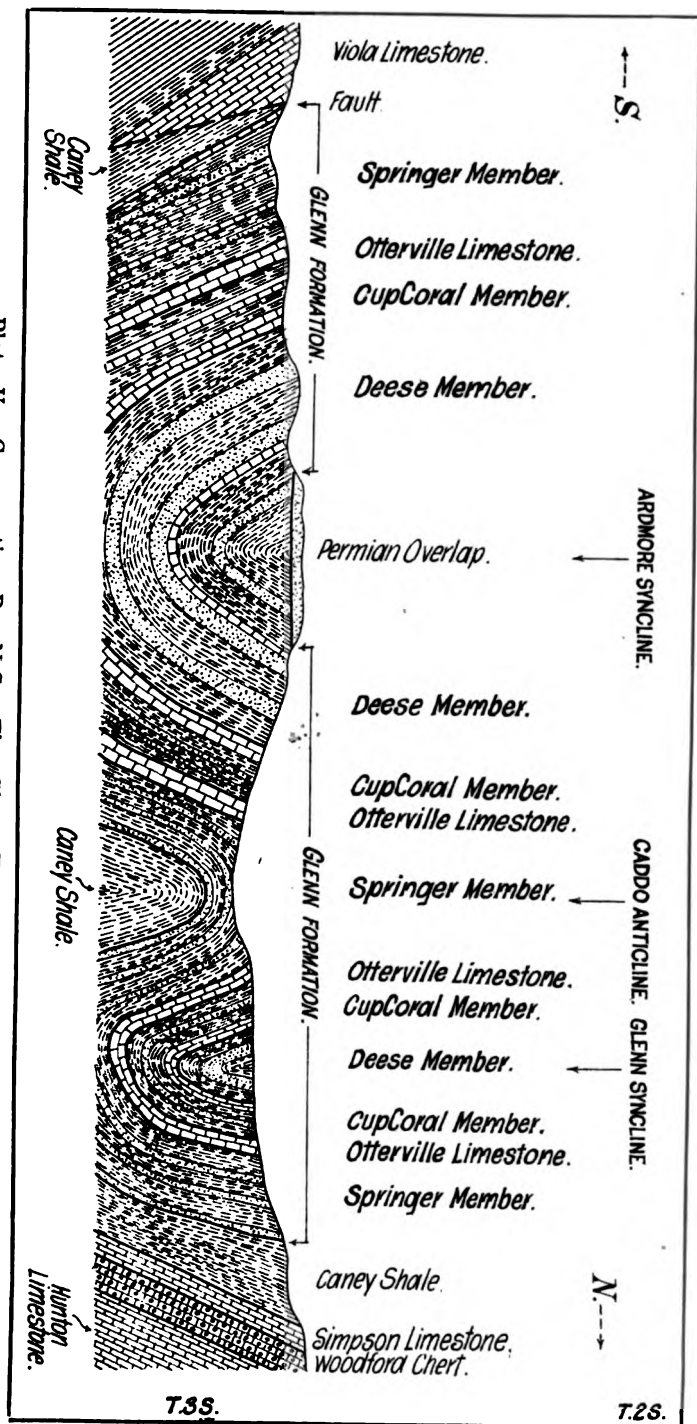


Plate V. Cross-section B. N-S. The Glenn Formation between the
 Criner Hills and the Arbuckle Mountains

broadens toward the south, the dip having flattened to 20 degrees on the south side.

CADDO ANTICLINE

The Caddo anticline is 12 miles long and is the largest fold in the Glenn formation. Its axis generally parallels both the Arbuckle Mountains and the Criner Hills. Rising on Henry House Creek in the eastern part of sec. 7, T. 3 S., R. 1 E., it extends southeastward across secs. 8, 16, 22, 35, and 36, T. 3 S., R. 1 E.; sec. 1, T. 4 S., R. 1 E.; and secs. 7, 17, 21, and 22, T. 4 S., R. 2 E. With the exception of the Hoxbar member and the basal part of the Springer, the whole Pennsylvanian sections are exposed along the flanks of the fold. The Springer and the Otterville limestone outcrops occur along the axis. The rocks dip from 90 degrees on the extreme north to 45 degrees on the south end.

GLENN SYNCLINE

The Glenn syncline lies between the Caddo anticline and the Arbuckle Mountains. Rising on Henry House Creek in the northeast corner of sec. 7, T. 3 S., R. 1 E., it extends southeastward across secs. 8, 9, 10, 11, 14, 13, T. 3 S., R. 1 E. The sediments forming this basin belong to the Otterville limestone, Cup Coral, and basal part of the Deese members. The rock dips from 90 degrees on the west end to 30 degrees east of Glenn.

BERWYN ANTICLINE

The Berwyn anticline is a narrow and steep fold located northwest of Berwyn. This fold affects only a few hundred feet of the sediments in the Deese member. The axis of this fold was not accurately located. Its approximate location is given on the map in Plate III.

ASPHALT DEPOSITS

There are numerous and extensive deposits of asphalt in the sediments of the Glenn formation. These deposits occur in three zones. South of Woodford, there are nine sandstones bearing asphalt. This zone is about 6 miles wide. The asphalt deposits are found in secs. 2, 3, 11, 12, and 13, T. 3 S., R. 1 W., secs. 18, 19, and 20, T. 3 S., R. 1 E. The sandstones are continuous but do not carry asphalt south of Caddo Creek.

The second zone of asphalt deposits occurs on the east side of Criner Hills. In this area are four asphalt bearing sandstones. These deposits are found in sec. 34, T. 4 S., R. 1 E., secs. 3, 4, 10, 14, 15, 23, 24, 25, and 26, T. 5 S., R. 1 E., and in sec. 7, T. 6 S., R. 2 E. There is also a deposit in sec. 21, T. 4 S., R. 1 E.

The third zone occurs in the horizontal sands of the Trinity formation, and is found in secs. 26, 27, and 35, T. 6 S., R. 2 E., and in secs. 1 and 2, T. 7 S., R. 2 E. The Glenn sediments, standing at an angle of about 65 degrees, underlie the Trinity sands and are the source of asphalt found in this area.

With the exception of the deposit in sec. 21, T. 4 S., R. 1 E., the three zones of asphalt are found at approximately the same relative stratigraphic position. The asphalt horizon of the Glenn formation includes the upper part of the Springer member, the Otterville limestone member, the Cup Coral member, and the basal part of the Deese member.

OIL AND GAS POSSIBILITIES

The Glenn sediments where exposed on the surface, are for the most part too strongly folded to permit an accumulation of oil and gas. There are only two areas where the dip of the rock are at angles low enough to furnish the physical conditions required for capping oil or gas. These are the Brock anticline on the west side of Criner Hills and an area including parts of secs. 11, 12, 13, and 14, T. 3 S., R. 1 E.

The Brock anticline is described under structure. The sediments forming this fold are stratigraphically below any of the asphalt sands found in the Glenn formations. The dip of the rock varies from 10 to 20 degrees and are not much stronger than the dip found in the lower producing sands of the Hewitt field. Since the sediment forming the Brock anticline is stratigraphically below the asphalt horizon of the Glenn formation, occurrence of oil or gas in these sediments is considered doubtful.*

*Editor's Note: The Crinerville well of the Amerada Petroleum Company located by Sidney Powers on this anticline is reported to flow 60 bbls. of oil at 1312 feet.

The structure of the area in secs. 11, 12, 13, and 14, T. 3 S., R. 1 E., consists of a broad nose plunging towards the south. This nose is formed by southeast dips in secs. 7, 8, and 18, T. 3 S., R. 2 E., and by southwest dips in sec. 13 and the northern part of sec. 14, and by west dips in the western part of

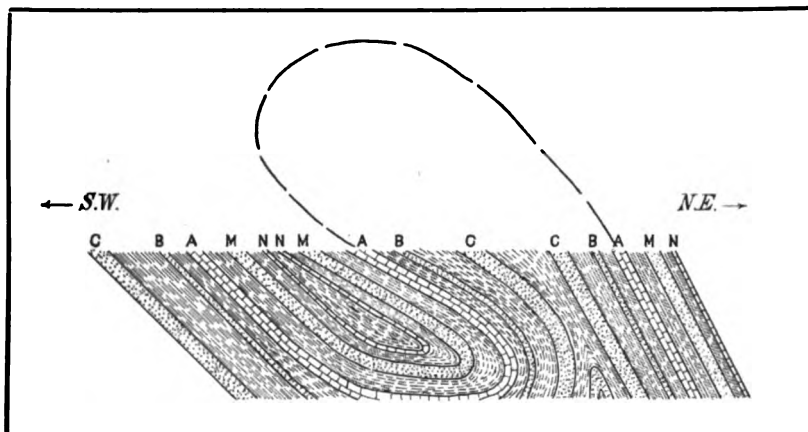


Figure I. Cross-section C. N. E.-S. W. Overturned Fold in Springer Member of the Glenn Formation East of Criner Hills.
Secs. 14 & 23 T. 5S., R. 1 E.

sec. 11, T. 3 S., R. 1 E. The dips vary from 10 to 30 degrees. The most prominent asphalt sand south of Woodford underlies this area at about a depth of 2,000 to 2,200 feet. This sandstone barren of asphalt is exposed on Caddo Creek in sec. 25, T. 3 S., R. 1 E., dipping northeast of Caddo anticline at an angle of 45 degrees. It comes to the surface again in sec. 1, T. 3 S., R. 1 E., dipping away from the mountains at an angle of 30 degrees.

South of the Arbuckle and Wichita Mountains the Glenn formation is very probably present over the greater portion of southern Oklahoma. Where not too strongly folded this formation may be considered an important source of oil and gas in this part of the State. The Hewitt field is an example of production from the Glenn sediments. The producing sands of the Hewitt field are very likely the equivalents of some of the asphalt sand exposed in the Glenn formation. On the Hewitt fold the upper sediments of the Glenn were removed by ero-

sion which occurred just prior to the invasion of the Redbed seas. Similar conditions would bring the asphalt horizon of the Glenn formation within reach of the drill in othehr places in southern Okiahoma.

With the exception of a few wells in the Healdton field, the Healdton, Wheeler, Loco, Robberson, and probably the Fox field, are most likely producing from sands which are post-Glenn. But even in these fields it is not unlikely that the Glenn is the original source of some of the production found in the younger sediments.

OIL GEOLOGY OF WARREN COUNTY, KENTUCKY

BY STUART ST. CLAIR*

INTRODUCTION

Prior to 1919 there were no producing oil wells in Warren County although there was considerable production in Allen County, the adjoining county on the east. Naturally, oil development should start on the east side of the county and it was in the spring of 1919 that the Moulder pool was opened. Gusher wells were brought in from the top of the Devonian limestone immediately underlying the black shale and at depths of little more than 400 feet. Other areas of small wells were opened in the eastern part of the county in the same year and also the Sledge pool, another gusher section. On November 3, 1919, the discovery well on the Davenport farm, four miles northwest of Bowling Green, was completed, and the real development of Warren County dates from this time although it was the spring and early summer of 1920 before the drilling campaign was in full swing. To add to the boom incident to the discovery of oil in the Bowling Green district in the limestone underlying the Devonian black shale, gusher wells were found in a stray sand in the St. Louis limestone at depths of about 450 feet.

TOPOGRAPHY

Warren County may be divided into two topographic provinces, the larger being the plateau area which extends from the eastern side of the county westward to the escarpment ridge, about four miles west of Bowling Green. The plateau is developed on the St. Louis and Ste. Genevieve limestones and is a rolling country deeply incised by the two main streams. Barren River which crosses the central part of the county in a general northwestward flow, and Drakes Creek, its principal tributary, which flows north through the east central part of the county. The drainage of most of the remaining area

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of the plateau is underground and the surface is marked by many sink-holes. The second topographic province is the highland area which occupies the northwestern part of the county and covers about one-third the area that the plateau country does. The highland area is developed chiefly on the Gasper limestone and the Cypress sandstone and is from 200 to 250 feet above the plateau. It is deeply dissected by the drainage, Green River, Barren River, and Gasper River.

GEOLOGY

The geology of Warren County which we must consider extends from the Niagaran limestone of Silurian age to the Cypress sandstone of the Chester, although the surficial geology is confined between the upper ledges of the Fort Payne of lower Mississippian age and the lower beds of the Pennsylvanian or Coal Measures.

Some deep tests for oil have penetrated the Ordovician limestone for probably as much as 600 feet or more in search of an equivalent of the Trenton oil formation. The well logs show prevailing limestones in the Ordovician and some oil is reported in the upper 100 feet of the series. The overlying Silurian, most of which is probably Niagaran, is made up chiefly of limestone with some shale. Some of the limestone beds are soft and earthy, and some are coarsely crystalline in texture. The thickness of the Silurian is between 80 and 100 feet. Overlying this is about 50 to 55 feet of Devonian limestone, light gray to brown in color, and referable to the "Corniferous," (Onandaga), the upper beds of which are the oil sands of northern Allen and eastern Warren counties. At the outcrop in Allen County the Devonian limestone is only a few feet thick, but in going westward the formation thickens materially. Most of the oil in the western half of Warren County is found at depths ranging from 68 to 135 feet below the Black Shale and, therefore, comes from rocks of Silurian age.

The Devonian black shale, which is the key-rock for sub-surface work, is about 50 feet thick in the eastern part of the county but thickens to about 100 feet in the western part, with an average in the oil belt west of Bowling Green between

75 and 90 feet. The variation in thickness over short distances is due to an unconformity with the overlying Mississippian and, therefore, structural work should preferably be based on the lower contact of the shale.

The basal Mississippian formation in Warren County is the New Providence shale which may be as much as 30 or 40 feet thick in the eastern part. High grade oil of an amber color is found in an horizon at or near the top and probably an equivalent of the Beaver sand of Wayne County. Overlying the New Providence is the Fort Payne, the upper ledges of which are exposed along Barren River in the extreme eastern part of the county. These ledges are chiefly chert but in unweathered or primary condition the formation is a siliceous limestone. The Fort Payne with the overlying Warsaw formation, which is chiefly fossiliferous limestone with some shale, the latter at the top, are about 220 feet thick in eastern Warren County, but they, (probably largely the Fort Payne), thicken in going westward, for in the deep pool area west of Bowling Green there is an interval of 330 to 340 feet from what is probably the basal part of the St. Louis to the top of the Black Shale. This would include the New Providence, if present.

The St. Louis limestone is the next younger formation and may be unconformable with the underlying Warsaw, a relation that is suggested by the absence of the Spergen limestone and cross-bedding and coarse-grained layers in the basal part of the formation. The St. Louis is a dense blue to gray limestone, very siliceous in many horizons as weathering produces large quantities of chert. The formation can be recognized by the coral *Lithostrotion basaltiforme* which is scattered over the surface as chert pieces. The shallow gusher wells in the western half of Warren County come from the lower or even basal limestone beds of the St. Louis. The thickness of the formation is from 335 to 350 feet.

The Ste. Genevieve, including the Fredonia member at the base, and the Gasper may be considered together for lithologically they are hard to separate as both are light colored limestones, and both are oolitic. The general absence of chert and *Lithostrotion basaltiforme* distinguishes them from the St.

Louis. The absence in Warren County of the O'Hara member of the Ste. Genevieve and the Bethel sandstone, which appear in Todd County to the southwest, may or may not denote a stratigraphic break at the base of the Gasper. The thickness of the Gasper and Ste. Genevieve is between 390 and 400 feet.

The Cypress sandstone overlies the Gasper and there is probably an unconformity between the two as the interval between the base of the Cypress and the top of the black shale in wells not far apart varies considerably. It must be borne in mind, however, that there are other breaks in the stratigraphic column which might account for these differences. The average interval is about 1085 feet.

In the northwestern corner of the county a few thin Chester formations above the Cypress come in, above which lies unconformably the Pennsylvanian sandstone and conglomerate.

STRUCTURE

The general structure of Warren County is a northwestward dipping monocline, the average dip being 30 to 40 feet to the mile. This regularity is broken by several uplift areas which extend in a general direction normal to the monoclinial dip. There is an uplift extending northeast-southwest along part of the eastern side of the county for along Bays Fork and Barren River there is a series of domes, the domes occupying many of the bends in the streams mentioned. Drakes Creek follows another line of uplift as many of the bends are structural. West of Bowling Green is probably the most discernible series of folds in the county, the uplift paralleling the escarpment ridge. Smaller paralleling folds lie a little southeast of the major fold. On the western side of the county Gasper River in part follows an uplift for well-defined domes occupy many of the river bends. Between the escarpment ridge to the east and Gasper River, the area has a very uniform monoclinial dip which is broken by terracing in a few localities. An interesting feature in the geology is the relation of the structure to the main drainage and to the topography in the western part of the county. Nearly all the prominent bends in Barren River and its three main tributaries are structural. The domes and

terraces in the highland area are strongly reflected in the topography.

OCCURRENCE OF THE OIL

Oil has been found at eight or nine different horizons in the geologic section that has been drilled through in Warren County, six having proven commercial. For brevity the six may be grouped into four so as to make formational units. These oil sands are the basal St. Louis in which the gusher wells in the Bowling Green area are found; the Beaver sand which occurs in the New Providence in the eastern part of the county and from which the amber oil is produced; the Devonian lime sand with its two pays; and the Niagaran lime sand.

St. Louis sand. The gusher wells in the Bowling Green district come from a sand at or near the base of the St. Louis limestone, probably in the lower 20 or 30 feet. The sand is a dark granular and well crystallized limestone. When drilled up it looks like dark carbonaceous sand but when larger fragments are bailed out it is seen to be crystalline and to contain many fragmentary fossil shells and is soft enough to be crushed between the fingers. Most of it will dissolve in acid and any residue is chiefly amorphous silica. This dark limestone may have a considerable thickness in some localities and intercalated with it are thin black to brown shale lenses. In the eastern pools of the county the interval between the basal St. Louis and the top of the Devonian black shale is about 250 feet; in the pools south of Bowling Green the interval is about 325 to 335 feet; in the pools several miles west of Bowling Green the interval is between 340 and 350 feet. This shows a thickening of the Mississippian formations below the St. Louis in going northwest, down dip, toward the Central Coal Basin of Western Kentucky.

The basal St. Louis oil sand is not persistent laterally for offsets to good wells may not find any oil and in many cases no water either. The writer suggests, therefore, that the basal beds where productive may occupy shallow erosional depressions in the underlying formation, or sink holes, which may have formed in the soluble Warsaw limestone during the inter-formational epoch, and that the black shale lenses may be

confined to areas where these depressions existed at the time of basal St. Louis deposition. Satisfactory records are not available nor was the writer able to examine the cuttings from enough wells to verify the presence or absence of these thin shale beds in wells which produced or did not produce oil from this sand. The presence of soft carbonaceous limestone, and in many wells studied carbonaceous black shale, coarsely crystalline limestone, abundant fossil fragments, water-worn chert fragments, and irregularity in a real distribution of the oil horizon, suggest basal sedimentation.

The St. Louis sand contains gas, oil, and salt water all of which are under great pressure in the big producing wells. The pressure is soon relieved, however, and the decline in production is very rapid, especially after several wells are drilled in the same locality. Wells that have flowed between 1000 and 2000 barrels the first day may be exhausted within a few weeks or at best a few months. There are exceptions, however, for a few are still producing as much as 50 barrels per day after three or four months pumping. Also a number are doing from 10 to 20 barrels after several months whose initial production was from 100 to 500 barrels. Some wells have come in flowing salt water, others have pumped salt water for a few hours or days and come on to oil. Each pool or unit in a pool has just so much fluid in it, evidently, and a well pumping salt water from a location down the dip from a producing well may draw the oil from the producing well, the former changing from water to oil. Shooting a well may ruin an offsetting producer, and in other cases dry holes may be drilled surrounding a producer. These facts show the spotted distribution of the St. Louis oil sand.

The oil and gas are probably indigenous to the basal beds of the St. Louis and come from the carbonaceous shale and the organisms, the fossil remains of which we now find in the limestone. The salt water is fossil sea water and is confined to the depression areas in which the basal oil horizon was deposited. The oil and gas have not migrated far from the point of origin and have arranged themselves, as far as pent up gas pressure would allow, according to their respective specific gravities in the small pools or units of a larger pool. The ac-

cumulation is only indirectly controlled by the structure of the rocks as the determining factor is the presence or absence of the basal oil horizon and this is dependent upon the sedimentary conditions that obtained at the beginning of St. Louis time. Where the basal oil horizon underlies a considerable area, structure has an influence on the accumulation and pools may coincide with the top of a dome or its flank. However, on many of the most pronounced structures in Warren County the basal St. Louis oil sand is absent.

Beaver sand. The Beaver sand is productive only in the eastern part of the county and is found at the top of the New Providence formation. The oil is very high grade and amber in color and is probably a product from the organic matter which was deposited with the underlying green colored shales. Accumulation is dependent entirely upon the presence or absence of the sand, which is lenticular, and secondarily upon the structure. Some of the wells come in at 100 barrels or better, but they soon decline to small production. Only a few wells are producing from this sand at the present time.

Devonian ("Corniferous") sand. The Devonian lime sand which underlies the black shale is productive principally in the eastern part of the county. There are two pays in the pools of this section and both are thought to be in the Devonian although the lower may be in the upper beds of the Silurian limestone. The first pay is the important producer and lies from a few feet to about ten feet below the base of the black shale, and is from five to ten feet thick. At the present time all the wells in this sand have small production, although the first wells in the Moulder and Sledge pools blew in at from 100 to 1000 barrels. The Moulder wells declined rapidly but the first few wells in the Sledge pool, by pinching them in, held up for some months and produced a great quantity of oil. The pay sand in these pools is brown in color and very porous, and the oil is under both gas and salt water pressure, but as the pressure is now relieved the wells are nearly exhausted.

In the field west of Bowling Green the Devonian produces very little oil, in fact the writer knows of only one commercial well, which is producing from a ten foot pay 36 feet below the

base of the black shale, although showings are reported at this horizon in many wells.

Silurian (Niagaran) sands. The Niagaran sands are the present big producers in Warren County and they lie from 68 to 130 feet below the black shale. The color of the pay sand is light or dark gray and the rock is soft and either earthy in appearance or crystalline, and contains very little grit.

The Niagaran limestone is apparently non-productive over the larger part of Warren County as oil in commercial quantities is found in it only within a restricted area in the west central part. Taking the western edge of Bowling Green as the apex, the producing area extends out fan-shaped covering an arc of about 125 degrees. The limit of the fan is but a short distance beyond the escarpment ridge, approximately four miles from the apex, but it may be extended a little farther. Within this fan area of production there are a number of non-productive sections where either the rock structure is too low or the sand condition is poor. Most of the producing wells are located on the tops and along the flanks of the anticlines and domes. In the saddles and in the synclines the sand conditions are generally poor, and little if any oil is found and rarely salt water to amount to anything.

The most pronounced line of structure, which is a series of domes, and upon which some of the best wells in the district are located, extends along the base of the escarpment ridge. The Niagaran sand is uniformly porous under this anticline which includes the Briggs dome, the Morris dome, the Scott dome, the Davenport dome, and across the river the domes in Winlock Bend of Barren River. Distinct saddles separate each of these domes. Paralleling this main anticline and lying to the east of it are other anticlines. The Davenport dome, which has a closure of 40 feet, is typical. The surface elevation near the river, Davenport lease, well No. 15 is 444 feet above sea-level, the depth to the top of the sand is 960 feet, bottom 967, and the base of the oil, therefore, 523 feet below sea-level. The pay is from 6 to 20 feet thick in this section and very little salt water is found in the oil formation. This water is under no pressure and is not bottom water but occurs directly in the

pay. Adjoining wells may show no water at all. This feature will be discussed under origin.

The top of the Niagaran sand in the wells west of Bowling Green is between 68 and 115 feet below the base of the black shale, and the pay streaks may vary in short lateral distances between these limits. The depths of the wells in the eastern part of the producing area west of Bowling Green are about 900 feet; in the western part, near the river where the surface elevation is about 450 feet, the depth is about 950 feet. Conforming to the topography the wells increase in depth and on the escarpment ridge the wells are 1300 feet and more.

Salt water was encountered in a few wells in the producing territory but the amount is negligible and it may not be found in offset wells. Outside the producing area a very few wells have struck salt water, but there are enough tests which encountered no salt water to indicate that there is no quantity or pressure of salt water behind the oil in the western part of Warren County.

SOURCE OF THE OIL

The source of the oil in the Devonian and the Silurian sands will only be discussed briefly. There seems to be but two premises, the oil is either indigenous to the limestones and probably to the sand horizons themselves, or the oil has migrated from the overlying Devonian black shales to the porous sand horizons below. The presence of a porous bed in the limestone is the all important factor in the accumulation of the oil although other factors may offset the presence of this requisite. Therefore, drilling may disclose a porous bed in the limestone which may or may not contain oil. On the other hand wells may be drilled on good structures and no oil or salt water found because the rock is tight, although fossils, which are evidence of pre-existent organic life, are found in what should be the oil pay, or adjacent to it. Again, wells drilled on favorable structures may find amply porous rock but be barren of oil or water. Salt water is found in quantity in the pools of Allen County and in the eastern side of Warren County, but little or no salt water is found in the Devonian or Silurian sands in other parts of the county.

The presence of porosity in the limestone is due to different

causes. The extreme eastern part of Warren County, and much of Allen County, are in an area where the porosity of the limestone is due to the solvent action of meteoric water which has entered at the outcrop of the limestone and has slowly percolated through the rock, dissolving the more soluble parts of the limestone and the saline residue on its travels down the dip of the strata. The distance from the outcrop to which this action has been effective is a function of the length of time the outcrop of these beds has been exposed to meteoric water. At the limit of the altered area there must be a large accumulation of water which is dammed back by the tight limestone which is yet unaffected by the meteoric water.¹ The extreme eastern side of Warren County is close to the line of separation of the porous area, produced by meteoric water solution, and the non-porous area, and the water trough must lie along this line. The occurrence of the oil and the great pressure behind it in the Moulder, Sledge, and adjoining pools showed this to be the true condition, and although considerable oil was recovered, the pools declined very rapidly and salt water in small or large quantities, depending upon the amount of the original pressure relieved, replaced the oil. The oil has evidently migrated from the fine-grained black shales to the underlying porous limestone through channels provided by joint planes and probably through incipient fissures which must be developed in rigid rock in folded areas such as are found in Allen and Warren Counties.

Outside of this area of porosity, there are several districts in the eastern half of the county in which there are a number of wells of small capacity. There is no pressure behind the oil and the accumulation is erratic. The small porosity of the rocks in these areas is probably due to recrystallization or dolomitization of the limestone. These wells do not form a group of any commercial importance.

In the producing area west of Bowling Green the Niagaran limestone appears to have ample porosity at the oil horizons to

¹The writer has given a more detailed description of this origin of porosity in his paper on the "Irvine Oil District, Kentucky." *Resources of Kentucky*, Vol. 1, No. 2, July 1919; and *American Institute of Mining Engineers*, Bull. 151, July 1919.

allow large accumulations. The porosity may be due to primary depositional conditions or it may be the result of secondary processes. The earthy appearance of much of the producing sand suggests the former; the crystallinity of some of the oil sand suggests the latter. If the sand porosity is the result of favorable depositional conditions and if the oil is indigenous to the Silurian limestone, the special conditions which must have existed during this stage of Silurian sedimentation were very local, for the small producing area is surrounded by a large barren area. If the source of the oil is the overlying black shale, the absence of oil in the Silurian limestone in the large barren area may be due to some condition which prevented its migration. Many wells barren of oil have gone through porous beds in the Niagaran limestone in which there is evidence of as much fauna from which the oil could originate as there is in the area where the Niagaran limestone is productive. If the limestone is the source of the oil, there appears to be no reason why the pools are not more generally distributed throughout the county and region. Also, since there is no hydraulic pressure in the oil horizons, if the oil was formed within the limestone there is no possibility of migration and, therefore, no reason for accumulation on the higher structural points. Yet the best wells in the Niagaran sands conform closely to the structure. As noted before, wells on the structures usually find good sand conditions; many wells close by in the saddles and synclines have poor sand conditions, generally. May there not, therefore be some peculiar relation between structure and sand condition and localization of oil accumulation. The following is a possible explanation of the origin and accumulation of the oil in the sands underlying and within a reasonable depth beneath the black shale.

The folding which parallels roughly the escarpment ridge, the division between the plateau and the highland areas, was probably more acute than in any other part of this general district, and produced a series of paralleling domes with interdomal saddles and synclines. The folding is less intense as the distance increases from the escarpment ridge. Jointing in the rocks show a general northeast-southwest and lesser northwest-southeast direction, a phenomenon which shows the axes

of stress and strain. This pronounced folding very probably produced similar jointing and probably some fissuring of the hard limestone beds which underlie the black shale. Through such channels there would be a direct connection between the petroliferous black shales and water-saturated limestone beds below. The less dense limestones are evidently saturated for shooting frequently brings in some salt water which can be quickly pumped out. There is, however, no hydraulic pressure behind the water. The oil would pass from the denser and finer grained shale to the more porous water-saturated limestone bed on account of the difference in the capillary pressures of oil and water (a phenomenon of surface tension). The interchange would progress to the point where equilibrium was established, at which time no further migration of the oil could take place either downward or a return upward. Deposition from the ascending water might close many of the channels of migration even before equilibrium was established. Naturally there were some beds in the limestone which were more porous than others and, therefore, contained more water, and to these more porous beds the oil would have the greater tendency to migrate.

The areas of jointing and even fissuring would be most pronounced where the folding was the severest. These areas would, therefore, coincide with the domes and anticlines, and the saddles and synclines would be affected to a much less extent, and probably in many cases not at all. Therefore, the migration of the oil from the black shale to the sand would take place primarily on the structures and to a lesser extent on the flanks or in the saddles or synclines. Likewise, there would be less chance for accumulation of oil in paying quantities the farther away from the line of major structural disturbance, because of a decrease in the amount of jointing and fissuring. The oil primarily accumulating on the structures would remain there for the water in the saturated porous beds would prevent the oil moving down the dip by gravity.

Some wells were drilled on promising-looking structures and porous rock was found at the horizon which is producing at no great distance away. The absence of oil in these wells is probably due to a lack of fissuring or jointing which extended

from the shale to the sand. In other words, the area did not receive enough stress during the formation of the folds to create the requisite jointing or fissuring. Many other wells drilled on good structures have failed to find any porous beds in the limestone underlying the black shale. The absence of either the channels for migration or a porous, water-saturated bed would prevent accumulation in commercial quantities.

The following primary facts can be explained by the theory or origin and accumulation which has been advanced. Localization of the producing area; presence of the oil on domes and anticlines without water pressure behind it (a modification of the present general interpretation of the anticlinal theory); absence of oil in favorable structures which are underlain by porous strata below the black shale; absence of oil under so large a part of Warren County but under which the same fossiliferous Devonian and Silurian limestones and peroliferous black shale extend. It would be hard to explain any of these four primary facts by the theory that postulates that the oil is indigenous to the limestone in which the accumulation has taken place.

CONCLUSIONS

With no definite views on the probable origin and accumulation of the oil in Warren County, many geologists would recommend the drilling of all domes and terraces for these structures prevail where the oil pools are located. But many similar structures have been drilled without success and there must be reasons for such results. Accepting the theory of origin and accumulation as outlined by the writer, an endeavor to extend production should be along the line of most intense folding, which is close to the escarpment ridge, and domes should be selected along this line for initial tests. It seems reasonable to believe that the folding should extend for some distance both ways from the Bowling Green field, but how far favorable sand conditions extend cannot be foretold. If a working theory of the origin of the porosity in the Niagaran limestone could be advanced, a prediction as to the extension or limits of the field might be made, as was done in the "Irvine Oil District, Kentucky."²

²Op. cit.

TOPOGRAPHIC CRITERIA OF OIL FIELD STRUCTURE

BY V. E. MONETT

The effect which the structure of sedimentary rocks has upon the topography has long been recognized by all field geologists, and topographic criteria are now used in most rapid reconnaissance work. The large number of producing wells which were located by the so-called "creekologists," and by those pseudo-geologists who consider anticlines and domes as purely topographic features, have only served to emphasize the close correspondence of drainage lines and other topographic features to structural conditions.

The danger in using such criteria lies in the temptation to use them as a basis for detailed work, especially where outcrops are few and correlation is difficult or impossible. There are so many limiting conditions that a statement of a few of them seem desirable in order to award topographic features their proper place in structural mapping.

A brief review of the physiographic laws governing the relation of surface features to rock position shows that: (1) In a region of horizontal or nearly horizontal sedimentary rocks, the relief may be slight or considerable but the hills tend to be of uniform height and to have uniform slopes. The streams are more or less equally developed and are dendritic (tree-like) in appearance. (2) In gently folded sedimentary rocks (dips less than 20 degrees) the resistant rocks form low ridges with a gentle dip slope in the direction of dip of the rocks and a steeper slope in the opposite direction. The main streams flow in relatively straight lines following the weaker formations and in the direction of the strike. The hills may be of irregular shape and of different elevations and may have either synclinal or anticlinal structure. (3) In closely folded sedimentary rocks the hills are all of the narrow ridge type and may be long straight ridges or else zig-zag ridges. They are steep on one side and have gentler slopes in the direction of

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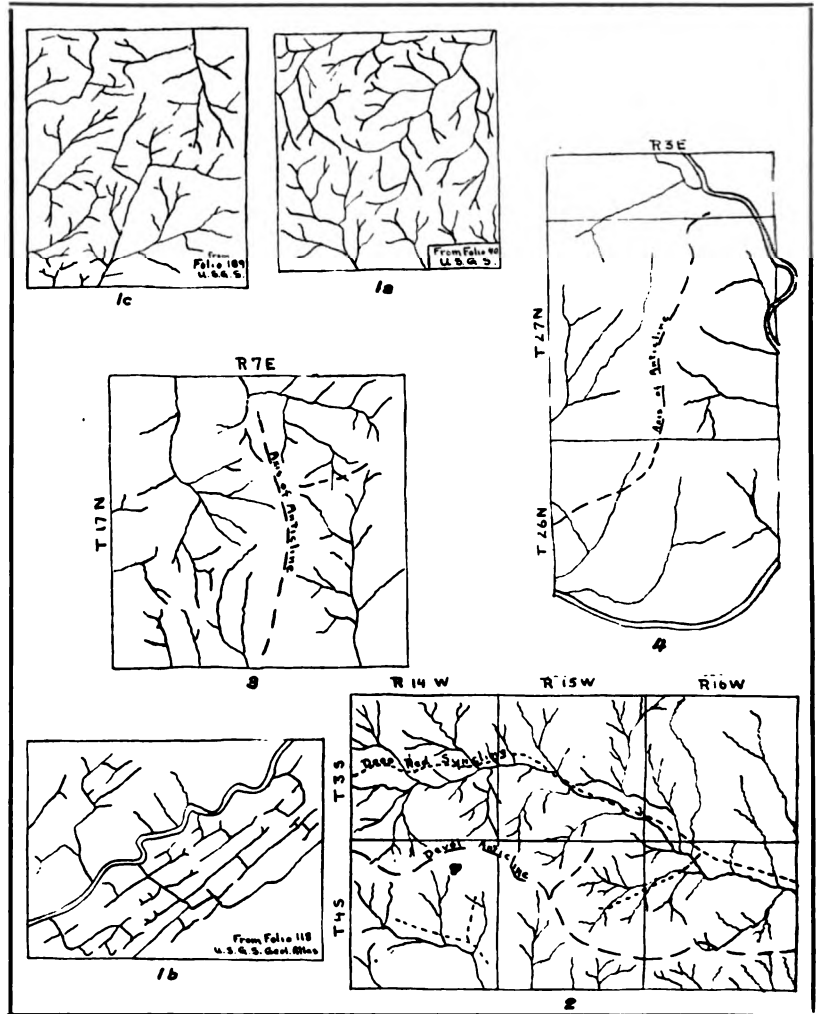


Plate I. 1a. Drainage in horizontal rocks, central part of Wartburg, Tenn., quadrangle. 1b. Drainage in closely folded sedimentary rocks, northwest part of Greenville, Tenn.—N. Cor. quadrangle. 1c. Drainage in gently folded sedimentary rocks, Barnesboro, Penn., quadrangle. 2. Reconnaissance map of the Grandfield district, Okla. (after Munn.) 3. Shamrock dome, Okla. (after Trout). 4. Part of Kay county, Okla. (after Trout).

dip of the rocks. The drainage is of the block type, with small weak streams flowing at right angles to the strike and the main streams running parallel to the strike and on the weaker rocks. The ridges are of unequal heights, and synclinal mountains are perhaps more common than anticlinal mountains.

These relations are clearly shown in Figures 1a, 1b, and 1c which represent actual drainage maps from selected areas. Figure 1a represents the dendritic drainage developed on horizontal rocks; figure 1b is an area of closely folded sediments and shows the characteristic block drainage; figure 1c, being developed on gently folded rocks, presents a drainage pattern that is a compromise between the other two types. The principal streams follow rather straight lines but the tributaries are somewhat dendritic.

Oil pools occur under all of the above three structural conditions. Rock outcrops and key horizons are usually abundant where dips are steep, so that topographic evidence is only made use of to the fullest extent where the type of folding is intermediate between case 1 and case 2 discussed above. A statement of the relation existing under such conditions would be about as follows: *When a considerable vertical section of more or less homogeneous sedimentary rocks are thrown into very gentle folds and eroded, the anticlines and domes will correspond approximately with the higher topographic areas, and the streams will tend to follow the synclinal axes.* True domes will give a radial drainage pattern.

Attention should be called to a number of qualifying phrases in this statement. In the first place it should be noted that if resistant sandstones or limestones are interbedded with soft shales, the tendency will be to develop escarpments facing the anticlinal axes, since the less resistant shales will be eroded much more rapidly than the other rocks. In the case of homogeneous sediments, or sediments which may differ in composition but have about the same resistance to erosion, the anticlinal axis is apparently not a place of weakness such as occurs along the axis of the sharp folds of more closely folded rocks. It offers the same resistance as the syncline and has the advantage of greater initial height. This advantage may be lost if the folding preceded emergence from below sea level, as slow

emergence would expose the anticline to erosion first. Another point which needs emphasis is that a single hill does not correspond to a dome but rather that a group of hills usually constitutes the "topographic high" area. Likewise a general drainage system, instead of a single stream, usually marks the location of the syncline. The maps (Plate I, figures 2, 3, and 4) will serve to illustrate these points. Only the drainage lines and the axes of the larger folds are indicated. Dozens of similar examples might be shown, but other structures, not very distant, may be found in which large streams cross the axis of the structure. Garber, Oklahoma field is a good example of this condition.

Even where resistant layers capable of forming escarpments occur, structures may be indicated by the direction of the scarp. In an area of general monoclinal dip, a semi-circular escarpment is good evidence of abnormal structure. Care is necessary to distinguish between meander scars of streams and true curving scarps due to rock position. The former can usually be identified by their habit of occurring first on one side of the stream and then the other. Gentle slopes which may be interpreted as dip slopes lend considerable weight to the evidence of curving escarpments when associated with them.

In areas of nearly flat topography the presence of structures may be indicated by the larger abrupt curves of the major streams. Numerous structures in Oklahoma along Arkansas, Cimarron, Canadian, and Red rivers have such a location, although it may be purely an accidental relation.

Perhaps no oil field better illustrates the value of topographic criteria than does the Gulf Coast field, where the earlier salt domes were located chiefly by the presence of low mounds or depressions and peculiar drainage relations. In the Pennsylvania fields, due to the complex structural history of the region, little dependence can be placed upon any such criteria. In the Warren quadrangle a low surface area is usually found to overlie the synclines, but in the Amity, Gaines, Elkland, and Tioga quadrangles the opposite condition usually exists.

In conclusion it may be said that the criteria of structure

afforded by streams, hills, escarpments, and other topographic features should be used only in reconnaissance work or else in those regions where other geological evidence is not obtainable. Even under such conditions it is doubtful whether the evidence is sufficiently strong to justify a favorable report or to warrant the expenditure of the money necessary to test a structure.

Note: Thruout this paper the word structure is used in accordance with the common oil field usage—i. e. structure favorable to the accumulation of oil, by which is usually meant dome or anticline. When used in any other way it is preceded by an adjective.

THE OIL SUPPLY OF THE UNITED STATES

BY U. S. GEOLOGICAL SURVEY

A review of the producing, probable, and possible oil-bearing regions in the United States by a joint committee composed of members of the American Association of Petroleum Geologists and of the United States Geological Survey has resulted in an inventory estimate that 9 billion barrels of oil recoverable by methods now in use remained in the ground in this country January 1, 1922.

Unlike our reserves of coal, iron, and copper, which are so large that apprehension of their early exhaustion is not justified, the oil reserves of the country, as the public has frequently been warned, appear adequate to supply the demand for only a limited number of years. The annual production of the country is now almost half a billion barrels, but the annual consumption, already well beyond the half billion mark, is still growing. For some years we have had to import oil, and with the growth in demand, our dependence on foreign oil has become steadily greater, in spite of our own increase in output. It is therefore evident that the people of the United States should be informed as fully as possible as to the reserves now left in this country, for without such information we can not appraise our probable dependence upon foreign supplies of oil, on the expanding use of which so much of modern civilization depends.

Fortunately estimates of our oil reserves can be made with far greater completeness and accuracy than ever before. During the last eight years a large part of the territory in the United States that may possibly contain oil has been studied in great detail by oil geologists; wildcatting has spread through "prospective" into many regions of "possible" and locally even into regions of "impossible" territory; old fields have been definitely outlined and new ones discovered; and finally, improvement in methods and special training in the calculation of oil reserves and of the depletion of oil properties have been developed to meet the requirements of the tax laws. Accord-

ingly, in order that the public may get the fullest benefit of this newly available information, the United States Geological Survey in March, 1921, invited the American Association of Petroleum Geologists to co-operate with it in a review of the producing, probable, and possible oil territory of the United States and in the compilation of an estimate of the petroleum remaining in the ground and recoverable by present methods. This invitation was promptly accepted by the association, which designated a number of its ablest members of well-known wide experience, good judgment, and high professional standing to serve with the oil geologists of the Survey as members of a joint committee.

The committee responsible for the original preparation of the estimates and finally for the adjustment and revision of the results in joint conference comprised F. W. DeWolf, state geologist of Illinois; W. E. Wrather, of Dallas, Tex.; Roswell H. Johnson, of Pittsburgh, Pa.; Wallace E. Pratt, of Houston, Tex.; Alexander W. McCoy, of Bartlesville, Okla.; Carl H. Beal, of San Francisco, Calif.; C. T. Lupton, of Denver, Colo.; Alexander Deussen, of Houston, Tex.; K. C. Heald, of Washington, D. C.; and G. C. Matson, of Tulsa, Okla., all representing the American Association of Petroleum Geologists; and, for the Federal Survey, David White, chief geologist, Chairman; W. T. Thom, jr., A. E. Fath, Kirtley F. Mather, R. C. Moore, state geologist of Kansas, and K. C. Heald. Mr. Heald represented both the Survey and the Association. These men were assisted in subcommittees by a large number of the leading oil geologists of the country, including oil-company geologists, directors of state geological surveys, and consulting geologists, who were especially familiar with the regions considered. All these co-operated whole-heartedly in the canvas of our oil reserves, and many oil companies also furnished confidential data for use in the preparation of estimates.

The calculations of the oil reserves in the proved and discovered fields are reasonably reliable, and those for regions regarded by the geologist as embracing "probable" future oil fields are based on all the available data and are entitled to high respect, but the committee wishes it most clearly understood that the estimates of oil in "possible" territory are abso-

lutely speculative and hazardous and that, although they represent the best judgment of the geologists, they nevertheless may be, at least in part, wildly erroneous. The questions involved are not only how much a particular doubtful region will yield, but whether it will furnish any oil whatever. On the whole the estimates are undoubtedly the best that have ever been made for the United States and better than have hitherto been prepared for any oil country or district of the world.

The estimates for local areas, fields, or districts have been consolidated by States, group of States, or broad regions in the case of nonproductive States.

*Estimated oil reserves of the United States, by
states or regions*

	Millions of barrels.
New York	100
Pennsylvania	260
West Virginia	200
Ohio	190
Indiana and Michigan	70
Illinois	440
Kentucky, Tennessee, northern Alabama, and northeastern Mississippi	175
Missouri, Iowa, North Dakota, Wisconsin, and Minnesota	40
Kansas	425
Oklahoma	1,340
Northern Louisiana and Arkansas	525
Texas, except Gulf Coast	670
Gulf Coast, Texas and Louisiana	2,100
Colorado, New Mexico, and Arizona	50
Wyoming	525
Montana, Nebraska, and South Dakota	100
Utah, Nevada, Oregon, Washington, and Idaho	80
California	1,850
Eastern Gulf Coastal Plain and Atlantic Coast States..	10
	9,150

The New England States are regarded as too unpromising to deserve consideration. Most of the northern peninsula of Michigan and the State of Minnesota are placed in the same category. The small quantities allocated to some other states indicate how little hope these geologists have of finding extensive oil fields in them. Some of these very doubtful regions will

give no oil, but others will make good the deficiencies. The estimates are as a whole distinctly conservative.

Of the total estimated oil reserves of the United States, amounting in round numbers to 9 billion barrels, 5 billion barrels may be classified as oil in sight and 4 billion barrels as prospective and possible. Rather more than 4 billion barrels should be assigned to the heavy-oil group. These oils will be recovered mainly in the Pacific Coast, Rocky Mountain, and Gulf States. The contents of the Lima-Indiana region, which yields oil of a distinctive type, are estimated at 40 million barrels. In general the so-called paraffin oils of moderate and high grade, as contrasted with the heavier oils, amount in all to about 5 billion barrels. The estimated reserves of high-grade oils of the Appalachian States are about 725 million barrels.

The estimated reserves are enough to satisfy the present requirements of the United States for only 20 years, if the oil could be taken out of the ground as fast as it is wanted. Should these estimates fall even so much as 2 billion barrels short of the actual recovery, that error of 22 per cent would be equivalent to but 4 years' supply, a relatively short extension of life. However, the committee expressly decries the too frequent assumption that inasmuch as the estimated reserves appear to be sufficient to meet the needs of the country at the present rate of consumption for 20 years, therefore the reserves will be exhausted at the end of that time or, at most, a few years later. This assumption is absolutely misleading, for the oil pools will not all be found within that length of time, drilling will be spread over many years, as the pools are found, and the wells can not be pumped dry so quickly. Individual wells will yield oil for more than a quarter of a century, and some of the wells will not have been drilled in 1950. In short, the oil can not all be discovered, much less taken from the earth in 20 years. The United States is already absolutely dependent on foreign countries to eke out her own production, and if the foreign oil can be produced, this dependence is sure to grow greater and greater as our own fields wane, except as artificial petroleum may be produced by the distillation of oil shales and coals, or some substitute for petroleum may be discovered.

All the estimates except those for one region, noted below, include only the oil recoverable from the ground by present methods, but it is practically certain that the percentage of oil to be recovered from the American oil fields will be vastly increased by the application of new and improved methods of recovery. At present, however, this phase of production may be regarded as in the experimental stage. Little has been definitely determined as to the applicability of "air pressure," "water drive," "gas pressure," "vacuum extraction," and other new methods to different regions, with their variation in conditions, or to the increase in production to be counted on from the use of these methods. The committee therefore feels that at present any estimates of such possible additional recoveries would probably contain errors enormously greater than those inherent in the estimates made on the basis of methods now in use. In only one region are the geologic conditions so well known and the experience with improved methods on a commercial basis so extensive and so long continued as to justify the formulation of estimates based on the results obtained. This is the region in northwestern Pennsylvania and southwestern New York where the "water drive" is now employed to obtain oil from the Bradford sand, which was supposed to be largely exhausted. Under the peculiar conditions there the use of this method will result in the recovery of a large quantity of oil that can not be recovered by ordinary methods of production. Allowance for the additional oil thus recovered has therefore been made in the estimates. It has already been found, however, that this method is not applicable to some other districts, and accordingly no allowance has been made for possible additional recovery through its use where its suitability to the local conditions has not been actually demonstrated.

In the light of these estimates as to the extent of our supplies of natural petroleum, the joint committee points out the stern obligation of the citizen, the producer, and the Government to give most serious study to the more complete extraction of the oil from the ground, as well as to the avoidance of waste, either through direct losses or through misuse of crude oil or its products.

DISCUSSION

ON THE STRATIGRAPHY OF NORTHEASTERN ARIZONA

In a recent privately published pamphlet entitled "Oil possibilities of the Holbrook area in northeast Arizona," Mr. Dorsey Hager has placed on record stratigraphic conclusions concerning this very interesting portion of the Colorado plateau country which are so widely at variance with the studies of other workers that, although hardly a subject for detailed review, discussion of Mr. Hager's chief correlations and his method of reaching them is called for. Portions of the paper have more recently appeared in the Mining and Oil Bulletin (Los Angeles), January and February, 1922, in which there appear very radical revisions. Through the courtesy of the author a "corrected copy" of the complete article has just been transmitted to the present writer.

Without reference to other contents of Mr. Hager's contribution, attention may be directed to the discussion of stratigraphy.

The geological formations of northeastern Arizona range in age from the Pre-Cambrian to the Tertiary but the units with which there is chief concern are between the Cambrian and the Cretaceous. The well known Grand Canyon region divisions which come within this interval include the Redwall limestone, Supai formation, Coconino sandstone, Kaibab limestone, Moenkopi formation Shinarump conglomerate, Chinle shale, Laplata sandstones and the McElmo formation. These, or equivalent stratigraphic divisions, are very widely distributed throughout the Navajo county of northeastern Arizona, (where they have been studied chiefly by Gregory¹), southern Utah, southwestern Colorado and north-eastern New Mexico. Holbrook is about 130 miles southeast of the Grand Canyon and near the southern edge of a broad, very gentle synclinal basin which involves the central part of the Navajo country. In the vicinity are exposed the Chinle shale, Shinarump conglomerate and the Moenkopi formation while not far distant are typical exposures of Kaibab limestone and the Coconino sandstone. In the escarpment of Mogollon Mesa to the south are exposed beds belonging to the Supai and Redwall. The section of this region is therefore essentially similar to that of the Grand Canyon country.

In southeastern Utah along San Juan river these are well exposed a series of reddish sandstones and shales and beneath them, in the vicinity of Goodridge, a considerable thickness of fossiliferous Pennsylvanian limestone. The latter, with some included sandstone and shale has been named by Woodruff² the Goodridge formation. The Goodridge formation is well known because it contains oil, but because a broad syncline

¹Gregory, H. E. Geology of the Navajo country, U. S. G. S., Prof. Paper 93, 1917.

²Woodruff, E. G., Petroleum and Natural Gas in Utah, U. S. G. S., Bull. 471 p. 76, 1912.

which lies between the San Juan oil field and the Grand Canyon carries the Pennsylvanian strata beneath the surface, it has not been possible to establish definitely the relation of the Goodridge beds to the Carboniferous deposits in the Grand Canyon district. The Goodridge, at its type locality, is overlain by red sandstones and shales which Woodruff and Gregory³ referred to the Moenkopi. Unlike the Moenkopi of other areas, however, there are in the beds above the Goodridge very massive sandstones, one of which on account of its remarkable development in the Canyon de Chelly has been called the De Chelly sandstone.⁴ The De Chelly sandstone is immediately overlain by the Shinarump conglomerate.

Following this brief introductory statement, it may be noted that Mr. Hager proposes to correlate the De Chelly sandstone of the Navajo country with the Coconino sandstone of the Grand Canyon region,—or rather the upper part of the De Chelly with the Coconino and the lower part with a part of the Supai. Presumably then, the Goodridge limestones are equivalent to the Redwall limestone of the Grand Canyon section, a correlation which is accordingly made. Mr. Hager is more definite. Referring to the "corrected copy" (Fig. 4) it is noted that the "Upper Redwall," is equivalent to the "Upper Goodridge" and that both are to be regarded as "Basal Supai"; the "Middle" and "Lower Goodridge" represent the "Lower Redwall." Unfortunately, however, the limitations of these subdivisions, their relation to the horizons of Pennsylvanian and Mississippian fossils which have been reported by other investigators and the basis for establishing the correlations are not indicated. Above the "Coconino" in the San Juan area Mr. Hager records Moenkopi, Holbrook (a new division), Shinarump and Chinle. Although the presence of a nearly normal section of Supai and Coconino beds above the Goodridge in the San Juan region is not prerequisite to correlation of the Goodridge strata with the Redwall, it appears to be Mr. Hager's conclusion that if the Goodridge and Redwall are equivalent, the Supai and Coconino must also be present in the San Juan district and that they are in fact represented by the shale and massive sandstone which Gregory and Woodruff regarded as Moenkopi and De Chelly, respectively. If the De Chelly is Coconino and the Goodridge is Redwall, oil may be sought in the Redwall at other places, as near Holbrook, and the depths involved in drilling which starts even above the De Chelly are not great.

The present writer does not propose in this discussion to take up in detail the validity of Mr. Hager's correlations. These are in part probably correct and in part erroneous. It may be noted that the interval reported by Woodruff between the base of the Laplata sandstone and the top of the Goodridge in the San Juan area is approximately the same (3000 feet) as that between the base of the Laplata and the top of the Redwall in the Grand Canyon district, and similarly as that between the

³Ibid.

⁴Gregory, H. E., loc. cit.

base of the Laplata and the top of the deep limestones encountered in the 3212-foot test of the Ohio Oil Company in the Circle Cliffs which started near the top of the Kaibab limestone. It appears certain that the considerable thickness of sandstone beneath the Kaibab limestone in the Circle Cliffs, about 65 miles northwest of the San Juan district, represents Supai and probably Coconino. It is very probable that equivalents of these units are also present in the San Juan district. However, that the Coconino is equivalent to the upper De Chelly, or to any part of the De Chelly may be doubted. Recent studies by H. D. Miser in the San Juan canyon and by Sidney Paige in the Cataract canyon of the Colorado River may throw important light on this point, but it appears very inadvisable to assert equivalence on such slender evidence or lack of any evidence—for Mr. Hager offers none—as is presented. Indeed, it is very uncertain in the paper under discussion what is meant by De Chelly. The typical De Chelly at the Canyon de Chelly, as described by Gregory⁵, immediately underlies the Shinarump conglomerate. The sandstone designated De Chelly in Mr. Hager's "corrected copy" and which is correlated with the Coconino underlies the Moenkopi (Hager) and is apparently quite distinct from another, much thinner sandstone above the Moenkopi and beneath the Shinarump which was marked in the first edition as De Chelly.

There are some errors in the premises used in the paper as a basis for interpretation of the historical geology of the region, such as the statement⁶ that Pennsylvanian rocks are absent in the Nacimiento Mountains of northwestern New Mexico. The writer has obtained large collections of typical Pennsylvanian fossils on the north and southeast flanks of this range.

The deficiencies which take most of the stratigraphic value from Mr. Hager's paper are a failure to submit evidence for hardly any of the correlations and a lack of precision in description of the stratigraphic units under discussion which in several instances makes it almost impossible even for the reader who is acquainted with the geology of the region, to follow. The presence of very glaring and almost self-evident miscorrelations in the first issue of the pamphlet, such as the reference of the upper part of the Navajo sandstone (Laplata) in Comb Wash, near Goodridge, Utah, to the Coconino, and the very large revisions in the "corrected copy" suggest that the evidence on which the entire paper is constructed is not very definite or thoroughly digested. An error, similarly suggestive of rather superficial acquaintance with the stratigraphic problems involved, to the effect that Woodruff and Gregory correlated the Coconino and Kaibab with the Moenkopi in the San Juan area has been corrected.

RAYMOND C. MOORE

⁵Gregory, H. E., *Geology of the Navajo country*, U. S. G. S., Prof. Paper 93, p. 32, 1917.

⁶Hager, Dorsey, *Oil Possibilities of the Holbrook area*, p. 22.

GEOLOGICAL NOTES

NOTES TO INVENTOR GEOLOGISTS

The members of the Association with an inventive type of mind, will perhaps be interested in the following ideas that have suggested themselves to the writer, who has carried them out in the crude way illustrated by the accompanying photographs.

The idea of a traveling machine that would automatically map to scale all of the roads driven over, is a dream that has occurred to many geologists doing reconnaissance work in unsectionized states. Theoretically such a machine is possible, using a gyroscopic compass to keep the map at all times properly oriented, and using a small wheel driven by a flexible cable to plot the distances passed over. Correspondence with the Sperry Gyroscope Company disclosed however that such an instrument cannot be adapted to an automobile, as the disturbances to the gyroscope caused by the jolting, rapid acceleration and retardation would soon deflect the instrument from its oriented position. So it seems that the self orienting mapping machine for geologists must still remain a dream.

If the self orienting feature is dispensed with, it is a comparatively easy matter to devise a machine that will plot the direction and distances driven over if the map board be kept properly oriented by hand.

For the geologist afoot, a traversing machine can be constructed to be operated in a manner similar to a tally register, but plot graphically the distances and courses of the traverse. The first photograph shows a crudely constructed machine for this purpose. A spring ratchet is pressed by the thumb for every double pace. The ratchet turns a screw, by means of which the recording pencil is slowly moved forward over the paper. The paper must be kept oriented by hand, revolving it around the pencil point as a center, so that the north-south line on it is kept parallel with the compass needle. In the hands of a man accustomed to pacing, very nice closures may be had with this simple instrument and the mind and hand freed from all counting and plotting.

The next instrument to be described has been given the awe-inspiring name of an intermittently recording microbarograph. This instrument was designed to record on a moving strip of paper the magnified fluctuations of an ordinary five inch surveying aneroid. This record then affords a means of correcting the readings of a twin aneroid carried by the geologist, who by noting the time of each reading is enabled to correct his readings in the evening without the usual systems of benchmarks and time corrections.

Since the sensitive mechanism of an aneroid is not strong enough to drag a pen over the paper, the record must be plotted without any friction whatever, the needle swinging freely except at the moment of record. The second illustration shows that this has been accomplished by adapting the clockwork recording mechanism from a thread type recording pyrometer to record the movements of the aneroid. The short needle of the

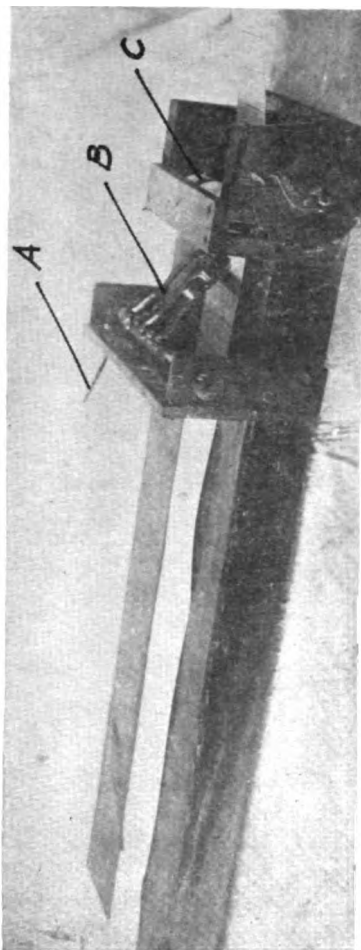
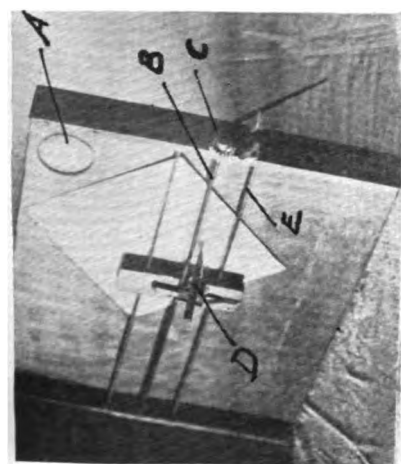
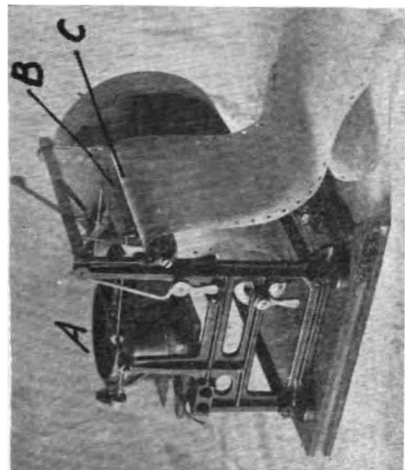


Plate I. *Upper left*, Traversing machine. (A, compass; B, screw; C, ratchet; D, pencil; E, guide rod). *Upper right*, Microbarograph. (A, five-inch aneroïd; B, recording lever which falls at half-minute intervals; C, long needle of aneroïd). *Lower*, Log-plotting machine. (A, pen-shifting lever; B, battery of pens; C, top roller.)

aneroid is removed and replaced by a longer one, this being the only change necessary to the aneroid. The long needle is passed over the inked thread and under the recording lever which falls at half minute intervals and forces the needle down for an instant against the inked thread which in turn records a point on the slowly moving paper. This paper moves by clockwork, one inch per hour, and the many points form a continuous line. Barometric changes of less than five feet can be read from the record and the record is wide enough to allow a range of five hundred feet of barometric pressure.

For the best results the aneroid carried by the geologist should be carefully matched with the one used for recording, by testing them together in a vacuum box until they are adjusted to work in unison.

The following is a brief outline of the method of field work with such an equipment. The barograph is transported to a place near the center of the area to be worked the needle being removed for the purpose. The needle is then replaced so that its reading on the ruled record coincides with the reading of the field instrument. The geologist then winds up the clock and goes into the field. With every elevation he takes, he also records the hour and minute. In the evening these readings are quickly corrected from the record of the barograph. To prevent the barograph from being molested it may be marked with a notice "Warning! Infernal Machine! Hands Off!"

The writer regrets that having but one instrument at his disposal he has never had an opportunity of thoroughly testing the practical applications of this method in the field. Many geologists believe that local disturbances would make it impossible for the worker to work more than a mile away from the barograph. Others are of the opinion that the so-called "holes in the air" reported by some aneroid workers, are due entirely to the use of small and inaccurate instruments.

The third instrument to be described is a log-plotting machine, made originally for Mr. M. J. Munn but not yet perfected. The most irksome task of the indoor geological worker is the plotting and coloring of the many well logs necessary in correlation work. A machine to do this work should be received with open arms by all who have had much of this work to do.

Let us analyse some of the features a successful log-plotting machine should have. It should be so designed that logs can be plotted by the "touch" or "sound" method and the eyes remain on the copy to be plotted and not needed for operating the machine. It must be accurate, it must plot thin formations as well as thick, it must not blot, it must be fool proof.

The third photograph shows an attempt to design such a machine. It does not fulfill all of the above requirements but may serve to stimulate the thoughts of others along this line.

The blank paper form, with the usual rulings is fed through the machine by a pair of small rollers operated by a small crank. One com-

plete revolution of the crank moves the form over a space corresponding to exactly 100 feet. Ten notches in the large disc mark the ten foot spaces with an audible click and with a little practice smaller divisions are easily estimated.

As the log form passes through the machine the various colors are wiped on from a battery of pens. Changes from one color to another are instantly made with a slight motion of the left hand.

A thin ribbon kept moist with ink from a thick flannel reservoir over each pen, spreads a broad even color over the spaces desired. If the ribbon is properly inked there is no surplus to cause blotting. A notch in the top roller however, allows the freshly inked area to pass through without contact with the roller. It has been found that the revolving rollers will measure off the depths so accurately that slight errors in the printed form are often brought to light. If the pens could be made to work as satisfactorily, everything would be lovely. The first pens tried were broad shading pens. They were too liberal with the ink and they had a limited capacity. Next ribbons were tried, fed from a moist flannel pad above. This method was suggested by the operator of a ruling machine, the pens of which are fed from such a reservoir. The skill required in keeping the reservoir properly saturated is a serious defect in the use of this method. The machine illustrated is equipped with pens of this type and it works nicely in the hands of a skilled operator but is sure to blot in the hands of others.

One of the surest ways to avoid the dangers of blotting would be to apply the colors by impact through colored ribbons as is done by the typewriter. This however makes the machine much more complex since several colored ribbons must be used and means added for giving each ribbon a progressive movement to provide fresh surface. The point to be brought out is, that the development of a successful log-plotting machine is not impossible by any means, and it is hoped that this article has stimulated the minds of the inventor-geologists so that the solution to this problem and some of the many other problems that daily present themselves, may soon become accomplished facts.

W. E. DODGE.

HAYNESVILLE FIELD, LOUISIANA

Development to date in the Haynesville field shows the existence of from two to three sands ranging through a vertical distance of from 20 to 50 feet. These sands are usually separated by sandy shales which in many instances form extremely hard caps. The oil appears to be more generally confined to the middle sand. The upper sand is very compact and rarely porous enough to contain either much oil or water. The lower sand is more porous but does not appear to be completely saturated with fluid. On the edge of the pool salt water may occur in all of these sands. In completing a well it appears desirable

not to drill into the lowest sand, lest in its unsaturated condition it drain off some of the oil from the upper sands, even though the well be located high on the structure. The salt water line is being defined in the south part of the pool with surprising regularity. A plane approximately 2500 feet below sea level seems to mark this horizon. It has been found that edge wells can be made most profitable by drilling into the oil sand only two or three feet. Even a foot or two below the critical level has led to a large influx of edge water with the oil. Packing off this water has helped somewhat.

L. P. TEAS.

December 12th, 1921.

AGE OF THE PRODUCING SAND, ELDORADO FIELD, ARKANSAS

The U. S. Geological Survey on February 7th, 1922, published a press notice regarding the age of the producing sand in the Eldorado field, which is quoted in the following paragraphs:

"Dr. L. W. Stephenson, of the United States Geological Survey, has determined the age of the producing oil sand definitely at the horizon of the Navarro formation, which is equivalent to nearly all of the Marlbrook marl, the Nacatoch sand, and the Arkadelphia clay, three formations belonging to the Upper Cretaceous series. A small fragment of the cuttlefish *Belemnitella americana* was obtained at a depth of 2,129 feet from the Gladys Belle Oil Co.'s Fitzgerald No. 4 well, in sec. 8, T. 18 S., R. 15 W. The known range of this genus and a supplementary study of the formations passed through by the wells strengthen the conclusion that the sand is the Nacatoch.

A few wells on the outskirts of this field have reached a sand about 400 feet below the Nacatoch. This deeper sand lies between the Nacatoch and the Blossom sand of the drillers. Proof is furnished by a specimen of *Crenella serica* (?) a small mollusk, found in a section of a core obtained at a depth of 2,552 feet from the Cooper-Henderson Oil Co.'s Hammond No. 1 well, in sec. 19, T. 17 S., R. 15 W. This species is common in beds of Navarro age but has not been found in beds older than the Navarro, except perhaps in a formation in New Jersey, where certain specimens were found that are questionably identified. The stratum from which the specimen found in the Hammond No. 1 well came is believed to be a part of the Marlbrook marl."

OCCURRENCE OF LIMESTONE IN NORTHEASTERN GARVIN COUNTY, OKLAHOMA

Near the southeastern corner of the northeast $\frac{1}{4}$ of the southeast $\frac{1}{4}$ of section 2, T. 4 N., R. 3 E., is found an outcrop of rather massive grayish white limestone. It is located in a small creek and for that reason is more or less limited in extent. The rocks surrounding this outcrop are Permian Redbeds, and though one would expect to find the limestone

on the hills within a half mile to the east of the creek, such is not the case.

The limestone is a very hard, close grained rock, heavily charged with calcite, rather brownish gray in fresh fracture though weathering white. There is about four feet of limestone exposed, below which is at least three feet of shale of practically the same color.

A careful search failed to bring to light any fossils by which the limestone could be identified, though there is a little doubt but that it is older than Permian. From general appearances the rock seems to be even older than Pennsylvanian though without fossils it is impossible to determine its exact age. The fact that it is older than Permian would prove that there is an unconformity of no mean proportions between the Permian and Pennsylvanian and this is of great importance both economically and technically.

About five miles to the east in T. 4 N., R. 4 E., is found an extensive outcrop of limestone which strikes almost due northeast and southwest. This limestone is dipping northwest at the rate of sixty to eighty feet per mile which is a higher rate of dip than is found in the Redbeds to the northwest.

HARVE LOOMIS.

REVIEWS AND NEW PUBLICATIONS

OIL LAND DEVELOPMENT AND VALUATION

BY R. P. McLAUGHLIN

McGraw-Hill Book Company, 1921.

The viewpoint of the author of this comprehensive little treatise is expressed in the preface, which informs the reader that "the information presented is based upon some ten years of investigations, a portion of which were made while administering the oil and gas conservation laws of the State of California. The operating conditions in the oil fields of California are of great diversity and embrace the general conditions obtaining elsewhere. Most of the obstacles encountered in the various fields of the world occur in some California field. The general principles involved in oil production are applicable to all oil fields."

The contributions of Mr. McLaughlin to the technology of oil production and conservation while he was State Oil and Gas Supervisor of California are known for their soundness and value in engineering practice. It cannot be disputed that the difficulties which are encountered in California oil fields are great, and in many cases extreme. For this reason the machinery and the methods used in drilling and production in Eastern and Mid-Continent fields had to be modified to meet the requirements of Pacific Coast conditions. This evolution affected rig building, the rotary drilling outfit, the underreamer, calf wheel and many other parts of the oil operator's apparatus. It is advantageous if improvements in machinery and in methods which have been developed in the California fields may be applied in every other field where conditions permit, for the oil business is no longer sectional.

With these thoughts in mind the experienced geologists, engineer or oil producer anywhere may apply to his particular problems facts and principles which are presented in Mr. McLaughlin's book. He will overlook the fact that it is distinctly a California product which only casually mentions other districts.

The book contains six chapters. Chapter I, Development Program, includes important points relative to the spacing of wells and the rate and method of development in planning oil field operations. Chapter II, Drilling of Wells, discusses the importance of a thorough understanding of geological conditions, and treats of methods of conservation by proper handling of the oil and gas and by exclusion of water. Chapter III, Assembling Information regarding Underground Conditions, contains much valuable material relating to graphic logs maps, cross-sections, peg models and progress reports. Chapter IV, Production of Oil, considers production record forms and graphs, most of which could be taken as models for leases in almost any field in the United States. Chapter V, Repairing, Deepening and Abandoning Wells, contains field maps and describes examples from California which are of general interest in relation to this subject. Chapter VI, The Value of

Oil Land, discusses the latest engineering methods of determining the amount of available oil, cost of production, drilling, pumping and market price of oil.

While, as has been indicated, the discussions apply mainly to California conditions, at least one half of the work pertains to subjects and principles which are general in application, and of the balance there is little which cannot be of interest to those outside of the Pacific Coast fields. Throughout the book there are many diagrams, cross-sections, and other illustrations which add to the value of the discussions.

Detailed review of the subjects considered would no doubt suggest many points which might have been treated somewhat differently and there are also minor corrections. An instance which would possibly be noted by some readers is the statement (p. 48) that use of the mud-laden fluid dates from 1915 when it was introduced by the U. S. Bureau of Mines in Oklahoma. It was actually introduced by members of the Bureau as early as 1913. There is an impression that some parts of the book, such as the last chapter, might very desirably have been elaborated.

H. B. GOODRICH.

Tulsa, Okla., Feb. 1, 1922.

OIL AND GAS PROSPECTS IN THE VICINITY OF BUTTON- WILLOW, KERN COUNTY, CALIFORNIA

BY R. M. FERGUSON

(Monthly Chapter Seventh Annual Report State Oil
and Gas Supervisor, California State Mining
Bureau, September, 1921.)

This is a short article designed to present the significant facts that have been revealed by the drilling near Buttonwillow, and the writer's conclusions concerning them.

Drilling in Buttonwillow resulted from the discovery that the productive oil zone in the Elk Hills to the west was not more than 3,000 feet below the top of the McKittrick formation. This fact, combined with evidence indicating that anticlinal structure was present in Buttonwillow, seemed justification for the tests. The conclusion that anticlinal structure exists at Buttonwillow is based upon the surface relief which shows a low swell in approximate alinement with the Coalinga, Kettleman Hills, and Lost Hills structures; the drainage lines in the bottom of San Joaquin Valley, which in the vicinity of Buttonwillow are parallel and margin the flanks of the supposed anticline instead of cutting across it; distinct dips to the southwest observed in alluvial deposits as opposed to dips to the northeast revealed by the logs of water wells; and the lack of artesian head on the ground water in this area, while at either side flowing wells could be obtained, as shown by Water Supply Paper 222 of the United States Geological Survey. After drill-

ing for oil was started core drilling was done by the Shell Company of California at the north end of the supposed anticline, and it is reported that anticlinal structure was proved by this means.

The beds passed through by such wells as have been drilled may be divided on the basis of lithology into three distinct groups: (1) 600-1200 feet of coarse sand with thick partings of yellow clay; (2) 1400 feet of blue clay with beds of hard sand; (3) carbonaceous shale beds. In these carbonaceous beds are fossils which appear to resemble forms found in the upper Etchegoin and Tulare formations in the Kettleman Hills. A bed of lignite reported in wells in the Elk Hills comes a short distance above the oil-bearing zone, and the writer has correlated the lignitic beds in the two districts.

Indications of oil in the Buttonwillow wells are confined to strong flows of natural gas which analyses show to contain a considerable proportion of ethane, and therefore possibly propane and butane, since these two hydrocarbons are commonly determined by analysts in terms of ethane; and to oil showings revealed by chloroform tests of drill cuttings. The latter can not be considered absolute evidence of the presence of even a small quantity of oil, since it has been found that resins and waxes that may be present in peat or lignites will give a discoloration of chloroform that is practically indistinguishable from that which results from petroleum.

The heavy flows of gas from the lignitic shales and sands in the Buttonwillow area raise the question as to the source of the oil and gas, not only in the Buttonwillow district, but also in other parts of California, and the writer expresses the belief that oil and gas in several of the San Joaquin fields have their origin in these shales rather than in the underlying diatomaceous beds of the Monterey.

Thus far no production test has been made on any of the wells, and until such a test is made no conclusions can be drawn regarding the possible productivity in the territory.

Jan. 1, 1922.

K. C. HEALD.

SALT DOMES OF NORTHEASTERN TEXAS

BY CHAS. A. CHENEY.

Oil and Gas Jour., Jan. 6, 1922, pp. 82-83

In this article Mr. Cheney advances theories, that are radically at variance with those of previous writers, to account for the formation of the salt domes of northeastern Texas. He presents the basis for his belief very concisely, and touches on its economic significance.

The major contention is that the Butler, Palestine, Keechi, Brooks, and Steen domes lie along the crest of an anticlinal fold. Their exposure is assumed to be due in part to cross folding of this anticline, and in part to erosion, which took place in pre-Tertiary time. The salt is considered a bedded deposit, originating in the interval between the deposition of

lower and upper Cretaceous, or else during lower Cretaceous time, and its apparent vertical thickness is ascribed to close folding.

Upon this theory Mr. Cheney bases conclusions that "the immediate vicinities of the domes are not favorable for exploration for petroleum in the upper Cretaceous"; that along the trend of this theoretical anticline there may be hidden domal areas of promise; and that "possibilities—would increase as one went north on the Butler-Steen anticline."

It is noteworthy that the above theory is based entirely upon assumptions none of which can at present be verified, and some of which seriously tax the imagination and credulity. First it is assumed that there is much more intense anticlinal folding in the great synclinal area where these domes are situated, than has taken place along the edges of this syncline. The distortion called for by this postulated folding is comparable to that in the Rocky Mountains, for Hopkins tells us that the beds on at least one of these domes have been elevated 3,000 feet—many times the elevation on any known fold involving Cretaceous strata in eastern Texas. In fact Mr. Cheney's theory calls for the fold to be closed in places—Appalachian structure within a few miles of the gentle dips of the Mexia anticline.

Profound erosion is demanded in the interval between the close of Cretaceous sedimentation and the beginning of Wilcox sedimentation. This erosion was called on to develop peaks, smoothly conical, or indeed almost cylindrical for their flanks must have approached verticality in places. They did not need the surprising feature of a salt bed capping them or lying but a short distance beneath their crests to make them unique among physiographic forms.

Perhaps most difficult of all to follow is the reasoning relating to the origin of the salt. The author concluded that it was laid down in lower Cretaceous time or in the interval between the deposition of lower and upper Cretaceous, supporting his belief by a citation of the occurrence of gypsum in the upper Cretaceous over the Sabine uplift. To get the salt to its present position in contact with upper Cretaceous strata without invoking either intrusion or solution and redeposition, it must either be surrounded by a circular fault, or else the salt mass itself was carved into mountains during a period of erosion. Either of these assumptions may, with consistency, be added to the previous ones.

Mr. Cheney points out an alignment of a number of salt domes which parallels the Balcones fault, and is at least approximately parallel to the line of anticlines of which the Mexia fold is one. Although the theoretical anticline he would have accompany this alignment cannot be considered seriously unless his assumptions are radically modified, there can be little doubt that this trend is of possible economic significance. It probably indicates the presence of a continuous zone of weakness along which there may be faults and folds of great importance.

K. C. HEALD.

LOWER CALIFORNIA

El Boletín del Petróleo, Vol. 11, No. 6, June 1921, published by the Secretaría de Industria, Comercio y Trabajo, Mexico City, and procurable from him for \$1.00 U. S., contains an article of 74 pages with two colored geologic maps and a number of photographs on Lower California. The title is "Informe sobre la geología y la existencia de los yacimientos petrolíferos en el distrito sur de la Baja California," by Miguel Bustamante. The geological map in five colors is very fanciful and inexact. Mr. N. H. Darton has also published "Geologic reconnaissance in Baja California," in the Journal of Geology for Nov.-Dec. 1921.

ISTHMUS OF TEHUANTEPEC

The same Boletín for April, 1921 contains a reprint of a paper by Arthur H. Redfield in Eng. & Min. Jour., Mar. 19, 1921. The title is "La industria del petróleo campos petrolíferos mexicanos en el istmo de Tehuantepec." The article is accompanied by a map in four colors $8\frac{1}{2} \times 13$ inches showing the location of the Isthmian salt domes. A deep sand oil well is reported to have been completed in December, 1921, on the Concepción dome. The Secretary also publishes a map of the same region in four colors scale 5 km. to 1 inch, size 14×25 inches, entitled "Plano de la Zona petrolífera del Istmo," another map, "Plano del Canton de Tuxpan" same scale, size $18 \times 24\frac{1}{2}$ inches and a third map "Carta de la zona petrolífera del norte de Veracruz y del las regiones colindantes," scale 10 km. to 1 inch, size 26×33 inches, each, in four colors, price \$1.00 U. S.

AT HOME AND ABROAD

MR. MAX A. PISHEL has returned to Tulsa and resumed his practice as consulting geologist, after a summer spent in California.

MR. G. L. ELLIS is with the Trans-Continental Oil Company at Duncan, Oklahoma.

MR. E. O. MARKHAM, of the Carter Oil Company, recently returned from New York for field work in Oklahoma.

MR. S. P. BORDEN has resigned from the Gulf Production Company and has established an office as consulting geologist in Shreveport, Louisiana.

MR. L. D. DONNELLY is with the Maracaibo Oil Exploration Corporation, 43 Exchange Place, New York City.

MR. A. F. CRIDER is consulting geologist for the Dixie Oil Company in Shreveport, working under the direction of Mr. Sylvan S. Price, Chief Geologist for the Dixie Oil Company, First National Bank Building, Tulsa, Oklahoma.

MR. PIERCE LARKIN, Tulsa, Oklahoma, is consulting geologist for the Prairie Oil & Gas Company.

MR. HENRY HINDS is now chief geologist and vice-president of the Alcalde Oil Corporation, with headquarters at Tulsa.

MR. LEON RUSS who has headquarters at 25 Broadway, New York City, has recently been at Mexia, Texas.

MR. E. DEGOLYER made a brief trip to Mexico during January.

MR. C. L. ARNETT is geologist for the York State Oil Company at Caney, Kansas.

MR. ROBERT ANDERSON is now in California.

MR. LUCIAN H. WALKER is in charge of the field party exploring in China for the Standard Oil Company of New York.

MR. LLOYD E. WELLS is with the Arkansas Natural Gas Company on the Gulf Coast.

MR. G. L. ELLIS is chief geologist for Snowdon Bros., with headquarters in Fort Worth, Texas.

STACEY AND BURRESS completed their well in the SE $\frac{1}{4}$ section 27 T. 18 N., R. 6 East, on the west side of the old Cushing Pool, Oklahoma, in the second break in the lime at a depth of 3,403 feet and have opened up a new pool which promises to be the forerunner of a number of pools in the second break around the edges of the old Cushing field.

MR. JOHN R. SUMAN, of the Rio Bravo Oil Company, has been in Tampico on a short trip.

MR. C. T. GRISWOLD is chief geologist for the Coline Oil Company in Oklahoma City.

MR. SAM W. WELLS AND MR. FORD BRADISH have established an office as consulting geologists in the Petroleum Building at Okmulgee, Oklahoma.

MR. E. W. SCUDDER is now geologist for the Gypsy Oil Company in Kansas, with headquarters at Winfield.

MR. GEORGE M. BEVIER is division geologist for the Atlantic Oil Producing Company in Houston, Texas.

The geologists of Denver and vicinity have organized the Rocky Mountain Association of Petroleum Geologists, with MAX BALL as President, J. M. DOUGLAS, Vice-president, and C. B. OSBORNE, Secretary-treasurer. There were seventeen members present at the first meeting and the report of the meeting states that thirty-one other geologists are members of the Association. Any geologist visiting Denver is asked to communicate with the secretary, Clarence B. Osborne, of the Midwest Refining Company, and they are invited to attend meetings of the organization while they are in Denver.

MR. EUGENE LILLY of St. Paul, Minn., is to sail February 4th for a tour of Egypt, Palestine and Europe, expecting to return early in the summer.

A recent statement in these columns to the effect that MR. E. L. ESTABROOK has the position of Chief Geologist for the Mid-West Refining Company is erroneous. MR. CARROLL H. WEGEMANN is Chief Geologist. Mr. Estabrook is engaged in special work for the company and has the title of Petroleum Production Engineer.

The firm of BAUER AND CLARK, consulting geologists, Okmulgee, Oklahoma, has been dissolved. Mr. C. Max Bauer, who was formerly with the U. S. Geological Survey, will have charge of geological work for the Mid Northern Oil Company, with headquarters at Billings, Montana. Mr. R. W. Clark will continue consulting work in Okmulgee.

DR. ED BLOESCH, who advises that his office is with Dr. O. Fischer, 721 Kennedy Bldg., Tulsa, has recently been in West Virginia.

MR. FREDERICK B. PLUMMER AND MR. RAYMOND C. MOORE are authors of a large report on the "Stratigraphy of the Pennsylvanian Formations of North-Central Texas," which has just been issued by the Bureau of Economic Geology and Technology, University of Texas. The report is accompanied by a large colored geological map of the Pennsylvanian area and detailed correlation charts.

Among members of the American Association of Petroleum Geologists who were present at the geological meetings in Amherst were ALAN BATEMAN, J. W. BEEDE, E. BLACKWELDER, E. DE GOLYER, F. W. DE WOLF, A. ELLISOR, A. E. FATH, K. C. HEALD, C. W. HONNESS, R. H. JOHNSON, J. F. KEMP, K. F. MATHER, R. C. MOORE, W. A. NELSON, S. PAIGE, C. SCHUCHEET, G. O. SMITH, DAVID WHITE AND W. E. WRATHER.

MR. F. S. PROUT is Consulting Geologist for the Douglass Oil Co., of Wichita, Kansas.

MR. RICHARD JONES, of the Humble Oil & Refining Co., has been transferred from Ardmore to Mexia, Texas.

MR. I. E. DUGAN is in charge of exploratory drilling for the Marland Refining Co.

MR. H. M. ROBINSON is working in east Texas.

MR. W. E. WRATHER will give a course of lectures during the Spring session of the University of Chicago on Petroleum Geology.

MR. JON A. UDDEN has lectured at the Rolla School of Mines, Rolla, Mo., on Subsurface Geology.

MR. J. A. OLIPHANT is consulting geologist for C. B. Peters, Tulsa, Okla.

MR. C. S. FORD is geologist for the Champlin Refining Co., of Enid, Okla.

MR. DORSEY HAGER, of Los Angeles, California, has recently issued a brochure of 31 pages entitled, "Oil Possibilities of the Holbrook Area in northeast Arizona."

The Tulsa Geological Society has elected the following officers for 1922: LUTHER H. WHITE, President, ED BLOESCH, Vice President, RICHARD HUGHES, Secretary, FRANK C. GREEN, Treasurer; HARRY F. WRIGHT, R. S. MCFARLAND AND J. V. HOWE, Councilors.

MR. K. C. HEALD represented the U. S. Geological Survey at the Osage sale, Dec. 12, 1921.

MR. DEAN E. WINCHESTER, of the Standard Oil Co., of New Jersey, is in Brazil.

MR. HARRY F. WRIGHT has moved from Wichita, Kan. to Tulsa, Okla.

MR. J. Q. MYERS of Fredonia, Kansas, is working in East Texas.

MR. C. F. BOWEN is in South America.

MR. H. HARPER MCKEE is in Venezuela.

THE TWELFTH SESSION OF THE INTERNATIONAL GEOLOGICAL CONGRESS will be held in Belgium next summer.

MR. A. D. BROKAW has been in Mexia in the interests of the Humphreys-Pure Oil interests.

MR. GEORGE C. MATSON has opened an office in Tulsa for the Schermerhorn Oil Co. Mr. C. W. Tomlinson is assistant to Mr. Schermerhorn in Ardmore, Okla.

MR. O. B. HOPKINS, Chief Geologist for the International Petroleum Co., Ltd., of Toronto, Canada, has left for the west coast of South America.

MR. W. P. HAYNES, with Mr. R. P. Walters as assistant, has gone to Europe for the Standard Oil Co., of New Jersey.

MR. G. A. ELLEDGE of the Atlantic-Cortez interests at Tampico has been in charge of drilling the first deep oil well ever completed with a diamond drill. The well is located in the Panuco field and was estimated as 1,000 barrels at 2,153 feet. The hole was drilled with a rotary drill to 1,400 feet where 4 inch casing was cemented. The remainder of the hole was drilled with a 3 $\frac{5}{8}$ -inch diamond bit which cuts a hole 3 13-16 inches in diameter. The "mudding" process was used in connection with the diamond drilling.

THE TULSA SECTION OF THE AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS elected the following officers for 1922: MR. H. B. GOODRICH, President, MR. J. A. UDDEN, MR. W. E. PRATT AND MR. SIDNEY POWERS, Vice Presidents, MR. R. S. MCFARLAND, Secretary.

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VI, 2

Fred B. Ely.

VOLUME 6

NUMBER 2

BULLETIN
OF THE
AMERICAN ASSOCIATION
OF
PETROLEUM GEOLOGISTS

RAYMOND C. MOORE,
Editor

Department of
Mineralogy & Petrography
HARVARD UNIVERSITY
CAMBRIDGE, MASS.

MARCH-APRIL 1922

LAWRENCE, KANSAS

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VOLUME VI

NUMBER 2

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RAYMOND C. MOORE
Editor

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MARCH—APRIL, 1922

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†Only a few copies of Volumes I and II are still available.

‡Except No. 2, double size number, \$3.50.

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CONTENTS

Oil Possibilities of Western Kansas.....	69
--	----

By Charles T. Lupton, Wallace Lee and L. R. Van Burgh

Discussion

Diamond Drilling for Production.....	91
--------------------------------------	----

By Frank A. Edson

The Diamond Drill in Oil Exploration.....	98
---	----

By Robert Davis Longyear

Discussion

The Petroleum Geology of a Part of the Western Peace River District, British Columbia.....	112
---	-----

By Edmund M. Spieker

DISCUSSION	139
------------------	-----

On Diamond Drilling, *P. W. Donovan.*

GEOLOGICAL NOTES	142
------------------------	-----

Preliminary Report on Underground Conditions in the Haynesville Oil Field, Louisiana, *W. W. Scott*; Investigations on Permeability and Absorption of "Sands" for Oil, Water, and Gas, with Reference to their Normal and Possible Yield, *A. F. Melcher*; Oil and Gas Prospects in Garfield County, Montana, *W. T. Thom, Jr., and C. E. Dobbin*; Age of the Barnett (Lower Bend) Shale of Central Texas, *Raymond C. Moore*; Oil and Gas Fields of Illinois; Southern Mexico.

REVIEWS AND NEW PUBLICATIONS.....	155
-----------------------------------	-----

Fuller's Earth Deposit at Olmstead, Ill., by *C. W. Parmalee, J. H. Hance*; The Monroe Gas Field, Louisiana, by *H. W. Bell and R. A.*

Bull. Am. Assn. Petrol. Geol.

Cattell, *J. W. Bostick*; *The Economic Aspects of Geology*, by C. K. Leith, *J. H. Hance*; *The Haynesville Field, Louisiana*; *Hunton Limestone Production in Oklahoma*; *Arkose North of the Arbuckle Mountains*.

THE ASSOCIATION ROUND TABLE.....162

The Seventh Annual Meeting of the American Association of Petroleum Geologists, Oklahoma City, Okla.; Methods of Electing Officers; Membership Applications Approved for Publication; A Meeting of the Association in the Fall.

AT HOME AND ABROAD.....170

Current News and Personal Items of the Profession.

BULLETIN
OF THE
AMERICAN ASSOCIATION
OF
PETROLEUM GEOLOGISTS

MARCH—APRIL, 1922

OIL POSSIBILITIES OF WESTERN KANSAS

BY CHARLES T. LUPTON, WALLACE LEE AND L. R. VAN BURGH

GENERAL STATEMENT

The area described in this report lies in the Great Plains Region of Western Kansas and embraces parts of six counties, namely, Scott, Lane, Ness, Logan, Gove and Trego. The greater part of the area lies between the Union Pacific and Missouri Pacific Railways.

Part of the area along Smoky Hill River was examined in the spring of 1920 and the greater part was examined during the winter of 1920-21, most of the work being done along the valley of Smoky Hill River in Gove and Logan counties.

SURFACE FEATURES

The topography of the region is in general that of the Great Plains, flat, treeless, undulating prairie at an elevation of about 3300 feet, cut by streams whose valleys are 200 to 300 feet lower, frequently being steep sided and abrupt and often having rim rocks of Tertiary conglomerate.

GEOLOGY

STRATIGRAPHY

The surface rocks of much of the Great Plains area are Tertiary, Quaternary and Recent deposits and alluvium, but the underlying Cretaceous rocks are usually exposed along the deeper stream valleys and their tributaries. In most of the

area examined rocks of Niobrara age are present, together with some Pierre in scattered localities. Below the Cretaceous are the Kiowa shale and the Cheyenne sandstone of Comanchean age, and beneath these are the Permian and Pennsylvanian which form the surface rocks of the eastern part of the state.

Tertiary

The Tertiary consists chiefly of conglomerate, calcareous sand, gravel and clay, with some impure limestone. These beds were deposited unconformably on the weathered and eroded post-Cretaceous surface. The relief of this surface was probably not less than 1500 feet and, while not having steep and abrupt slopes, it was probably more intricately dissected than the present surface. The approximate contact of the Tertiary with older deposits is shown by Darton¹.

Cretaceous

Pierre—The Pierre is the highest formation of the Cretaceous exposed, and is brought down in a synclinal area in the western part of T. 15 S., R. 32 W. It consists of the usual type of dark and blackish shales. It frequently weathers to a yellowish gray and outcrops exhibit abundant selenite crystals. No fossils were observed. Very few outcrops of Pierre occur in the area.

Niobrara—With the exception of the above mentioned scattered outcrops of Pierre, the Niobrara is the only Cretaceous formation exposed. It consists almost entirely of chalk and contains numerous thin shell beds of *Ostrea congesta*, particularly in the middle part, and thin marcasite bands and nodules. Thin and very localized lignite seams are sometimes found. The color varies from creamy white to yellow, buff and blue. It contains no definite datum planes, although certain zones are distinguishable. A rough classification of horizons may be based upon certain physical characteristics but there is no sharp line of demarcation between the divisions. The formation contains abundant *Ostrea* and huge *Inocerami* and fossil remains of vertebrates.

¹Darton, N. H. The Structure of Parts of the Central Great Plains: U. S. Geol. Survey. Bull. 691A, Plate 1, 1918.

The following section measured in Sec. 17, T. 15 S., R. 32 W., shows the variations in the upper 300 feet.

Section of Niobrara beds measured in Sec. 17, T. 15, R. 32 W.

Pierre shale.

Niobrara chalk

- | | |
|---|---------|
| 5. Chalk, bluish and buff, feebly bedded, with <i>Ostrea</i> and other fossils..... | 18 ft. |
| 4. Yellow, buff chalk, distinctly bedded, no <i>Ostrea</i> . When fresh has deep blue color..... | 100 ft. |
| 3. Blue <i>Ostrea</i> -bearing chalk with faint lamination, not bedded. Locally carries coarse <i>Ostrea</i> 1 inch in diameter..... | 32 ft. |
| 2. Soft, white, faintly laminated chalk, <i>Ostrea</i> not abundant though occasionally present but not in sheets. Practically free from fossils and ironstone bands..... | 33 ft. |
| 1. Blue slaty chalk with ironstone bands and sheeted aggregations of <i>Ostrea</i> | 117 ft. |
| Total | 300 ft. |

Bed 4 is the most striking horizon and can usually be recognized by the color, but where unweathered and fresh can be distinguished by the slightly darker, bluish color and the distinctive bedding. Bed 2 is often not strikingly distinguished but Bed 1 is definitely characterized by the presence of well marked, weathered, ferruginous bands, sheeted aggregations of *Ostrea* and an abundance of huge thin shelled *Inocerami*.

Lower in the section and lower in the valley of the Smoky Hill these beds are succeeded by white and bluish chalk, with a change in the type of *Inocerami*. This is succeeded downward in turn by a zone of alternating-bedded blue and white chalk and at the base is the strikingly characteristic Ft. Hays limestone with its well bedded deposits of white chalk, about 70 feet thick.

The Niobrara, being a decidedly brittle member, has practically no capacity for internal adjustment of strains, so that the area is conspicuously affected by minor faulting. Evidences of major faulting of a deep seated character are also present.

The total thickness of the Niobrara is about 700 feet.

Cretaceous Below the Niobrara

No exposures of the Cretaceous below the Niobrara occur in

this area. The following composite section from outcrops farther east is reported by Darton².

*Composite section of Benton and Dakota formations in western Kansas
(after Darton)*

Benton formation

Carlile shale

Victoria or Blue Hills shale

Loose dark blue gray shale.....100 ft.

Ostrea shale.

Clay or soft blue gray shale with thin limestone beds.....150 ft.

Greenhorn limestone.

Thin limestones and shale..... 65 ft.

Graneros shale.

Bituminous shale..... 30 ft.

Dakota sandstone

Brown cross-bedded sandstone and shale.....250 ft.

In view of well logs now available in western Kansas the thickness of the Benton which is here reported is too low. Its total thickness is over 400 feet. In a well drilled in Sec. 27, T. 15 S., R. 31 W., by the Plateau Oil Corporation the Benton was found to be 435 feet thick and was composed mostly of loose dark blue, gray and brown shales with 70 feet of limestone.

Dakota At the outcrop the upper part of the Dakota consists of gypsiferous and salty shales, but in the well drilled north of Garden City, in Sec. 35, T. 21 S., R. 31 W., several beds of sandstone 15 to 20 feet thick occur in upper part, which is 100 feet thick in the log. In the sections measured at the outcrop there is frequently found below the upper division a thin bed of coal or black shale, which seems to be represented in the Garden City log by 10 feet of black shale. The lower part of the Dakota consists of alternating sands and shales aggregating 190 feet in the Garden City log. There were three sands in this part, 13, 58 and 17 feet thick. The total thickness of the Dakota in this well was 321 feet and it contained 7 sands.

In the Plateau well the Dakota was 225 feet thick and consisted of alternating sandstone and shales. Four sands, from 15 to 20 feet in thickness, were present. A well drilled near Utica in Sec. 1, T. 17 S., R. 26 W., showed only 120 feet of Dakota containing two sands, one 10 feet and the other 15 feet thick.

²Darton, N. H. Preliminary Report on the Geology and Underground Water Resources of the Central Great Plains; U. S. Geol. Survey. Professional Paper No. 132.

Comanchean

Comanchean beds outcrop only in scattered localities along Medicine Lodge and Cimarron rivers and in McPherson County, the outcrop in all other localities where it might be expected being covered by the overlapping Tertiary. At the

INDEX MAP OF WESTERN KANSAS.

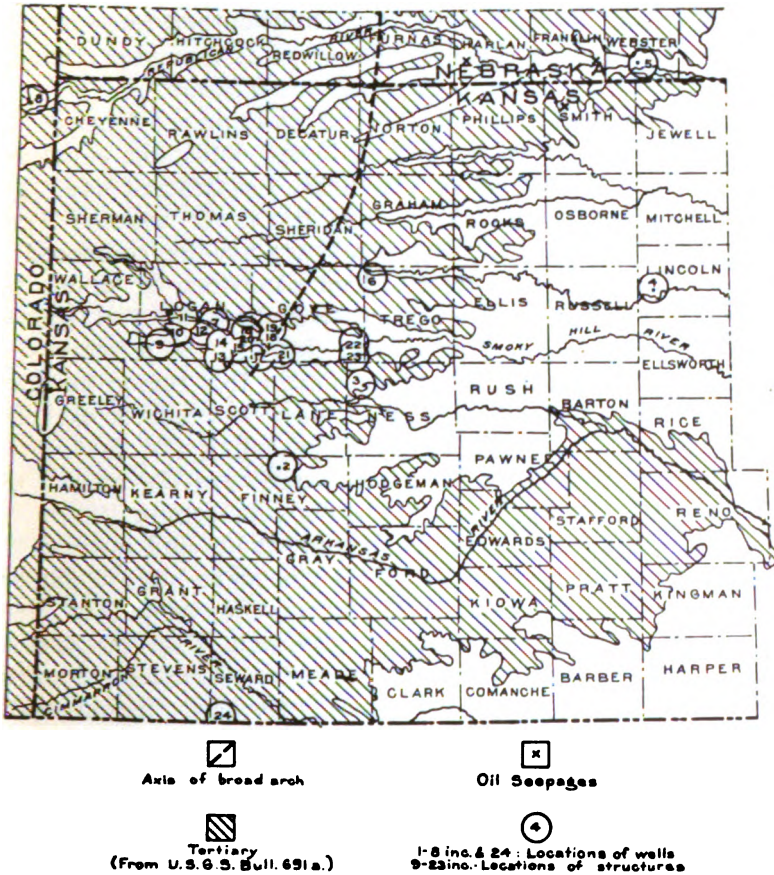


Plate I

outcrop in southwestern Kansas this division consists of a basal sandstone formation 40 to 50 feet thick, called the Cheyenne, and an upper formation consisting of black and dark shale and thin limestones 125 feet or more in thickness, called

the Kiowa. They here have a maximum thickness of 200 feet. The log of the Garden City well showed a thickness of 380 feet, a hitherto unknown thickness for this region. This log showed 5 sands in the Comanchean 7 to 69 feet thick. The Utica log showed 420 feet of Comanchean, and the Plateau log 400 feet.

The Kiowa beds of Western Kansas are northern representatives of the Washita of Texas, the highest division of Comanchean age. In northeastern New Mexico and southeastern Colorado they are found above the Morrison, which is separated from the upper Red Beds by a marked angular unconformity.

In southeastern Colorado the Dakota-Comanche group consists essentially of an upper and lower sandstone, separated by a relatively thin member (20 feet) of shales and clay. The upper member (true Dakota) and the lower member (now known to be of Comanchean age) are usually composed of massive more or less cross-bedded sandstone of about the same thickness, the whole aggregating about 250 feet, though in some localities it is somewhat thicker. It appears that after the pre-Morrison peneplanation in this region an early movement of the Rocky Mountain flexure occurred, carrying a downward fold along an axis paralleling the Rockies in which the fresh water Morrison beds were deposited. As the movement progressed, the sediments coming from the rising land surface to the west became sandy and invaded the basin, causing the deposition of the Cheyenne beds of Kansas and the lower Purgatoire formation of Colorado. The sands were more abundant in eastern Colorado than in Kansas, where they were more remote from the source, so that the more or less homogeneous sandstone (locally conglomeratic) of Colorado became interstratified with shale in the Kansas section. In Kiowa time this basin was invaded by the Washita sea with deposition of marine shales in western Kansas, while the corresponding interval in Colorado is also occupied by shales which are here much thinner. It is probable that while the center of the basin was receiving these sediments the western margin was either still receiving sand or that the shore line had advanced eastward by sedimentation. After the withdrawal of the Comanche sea sandy sedimentation was renewed in Dakota time throughout the basin, but the

sands continued to be thicker and more homogeneous toward the west than farther east in the basin.

The well drilled northeast of Garden City shows a thickness of 381 feet of Comanchean beds, consisting of alternating sandstones and shales, many of the latter being black. At the outcrop in Kiowa County the thickness is scarcely 200 feet and in eastern Colorado the Comanchean below the true Dakota is rarely more than 200 feet thick, though some exceptional local thicknesses are reported. It appears, therefore, that in the basin east of the Rockies beneath younger beds there are deposits of Comanchean age which are at least locally thicker than exposed at the outcrop and that these beds in the longitude of Garden City consist largely of alternating beds of sandstone and black shale.

The Cheyenne sandstone at its outcrop near Belvidere, Kiowa County, Kansas, is a white to yellowish, cross-bedded, saccharoidal sandstone. The Kiowa shales are chiefly dark to blue black and in the lower part becomes increasingly carbonaceous. Exposures weather out and resemble to some extent the paper shales of other regions, but though the term has been applied to certain beds in the Kiowa, the Kiowa shales are not so tough.

Permian and Pennsylvanian

The Comanchean rests unconformably on the Permian of Kansas. At the outcrop in the southern part of the state they overlie the Red Beds and in the northern part they rest on younger beds of the Permian. In the Garden City and Utica wells the Red Beds were encountered.

A deep well drilled at Vesper in Lincoln County, Kansas, starting almost immediately below the Dakota, penetrated the following strata at the depths indicated:

Strata penetrated in the Vesper well, Lincoln County, Kansas

	Thickness in feet	Depth in feet
Salt	136	742
Sand	24	1276
Sand	5	2302
Sand	13	2548
Sand	58	2755
Several thin sandstones.....		2887-2938
Sand	120	3215
Mississippian limestone		3335

The presence of Cretaceous beds and the western dip of the Carboniferous strata combine to make the depths to these horizons considerably greater in Logan and Gove counties than in Lincoln County. About 600 feet more of Permian beds are present in the Utica well than in Lincoln County.

The Permian consists of typical Red Beds, red sandstone, clays, shales and sandy shales with some limestone and beds of salt. A show of oil was reported in the Permian about 500 feet above the base in the Vesper well. In a well drilled north

**TWIN BUTTES ANTICLINE
LOGAN COUNTY, KANSAS**

CONTOURS SKETCHED ON DIPS
INTERVAL 50 FEET

WALLACE LEE, GEOLOGIST.

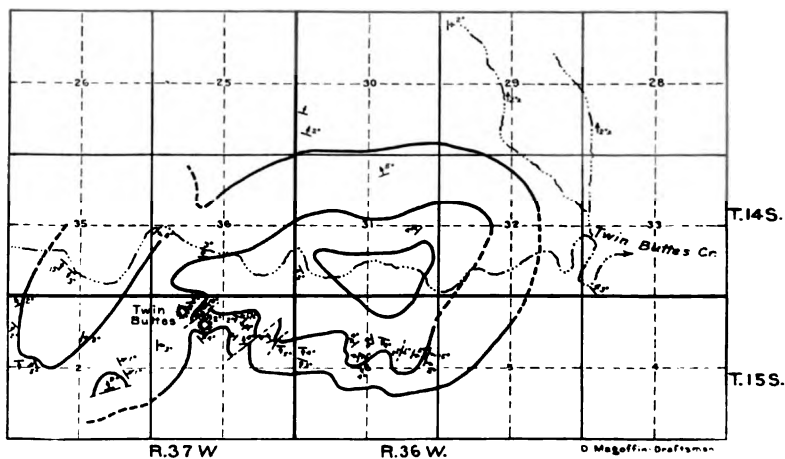


Plate II

of Collyer in Sec. 5, T. 11 S., R. 25 W., oil was found at a depth of approximately 1860 feet in a sand in the Red Beds about 400 feet from the top. Oil rose 300 feet in a 10 inch casing. While trying to pull the casing the top of the rig was pulled in and later the casing was pulled in two, and the well has not been completed. While the Permian is not considered as a probable source of oil, yet this amount of oil would suggest that oil might be found in the Permian in commercial amounts, particularly in connection with faults, as this oil is probably migrating upward through faults from the underlying Pennsylvanian.

The depth to the Permian and Pennsylvanian in the area special consideration in this paper will be much greater than at Vesper, due to the westward dip of the strata and to the presence of a greater thickness of the Cretaceous. The following table gives the approximate depths to the horizons reported in the Vesper well for the district including Scott, Lane, Ness, Logan, Gove and Trego counties, the figures being reckoned from the base of the Niobrara.

Approximate depth below Niobrara chalk of deep sands to be encountered in Scott, Lane, Ness, Logan, Gove and Trego Counties, Kansas

	Depth in feet
Top of salt	2200
Sand 24 feet	2800
Sand 5 feet	3800
Sand 58 feet	4250
Sand 120 feet	4700

The Vesper well is located 120 miles east of the area here under discussion and considerable variation may in consequence be expected in the thickness and number of sands.

In addition to the above sands in the Pennsylvanian there are a number of thick sands in the Permian portion of the logs of Utica and Garden City which, while not looked upon very favorably as oil reservoirs, may be regarded as possibilities.

Oil has been produced from the Red Beds of Permian and Triassic age in the following fields: Garber, Billings, Blackwell, Caddo-Cement, Lawton and Healdton, in Oklahoma; Burkburnett and Electra, in Texas; Dallas and Hamilton Dome, in Wyoming.

STRUCTURE

BLACK HILLS ARCH

The axis of the broad gentle arch which extends from the Black Hills of South Dakota across Nebraska in a southeasterly direction through Stockville and Cambridge, swings south and enters Kansas near the northwest corner of Norton County. From this place it gradually trends to the southwest and dies out south of Smoky Hill Valley. This arch was discovered by Darton³, the fold being shown in a general

³Darton, N. H. The Structure of Parts of the Great Plains: U. S. Geol. Survey. Bull. 691A, p. 11, 1918.

way on Plate I in the report referred to just above. This broad arch is much concealed by beds of Tertiary, Quaternary and Recent ages through Nebraska and western Kansas, its position having been determined largely by drill holes. In southern Nebraska the exposures along Republican River, as pointed out by Condra⁴, reveal the presence of this arch.

As shown on Plate I, Tertiary beds cover nearly all of

CHALK CREEK DOME
LOGAN AND SCOTT COUNTIES, KANSAS

CONTOURS SKETCHED ON DIPS
INTERVAL 50 FEET

L. R. VAN BURGH, GEOLOGIST.

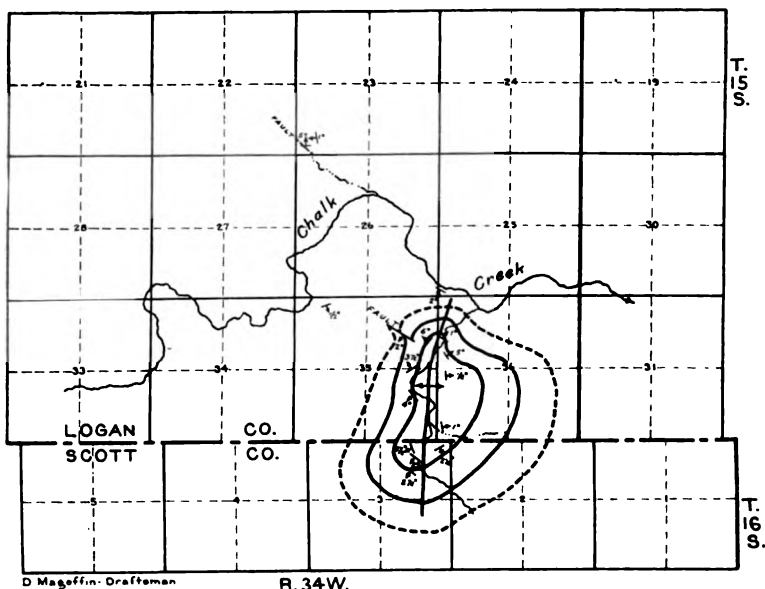


Plate III

western Kansas except along Smoky Hill River and some of its tributaries. This broad arch is registered here and has developed on it numerous minor anticlines and domes with their axis in general parallel to the axis of the broad arch.

MINOR DOMES AND ANTICLINES

Eighteen domes and anticlines have been mapped in the

⁴Condra, G. E. Geology and Water Resources of the Republican River Valley and Adjacent Areas, Nebraska: U. S. Geol. Survey Water Supply Paper No. 216, p. 11, 1907.

broad valley of the Smoky Hill River in Gove and Logan counties, Kansas. At least eight of these domes and anticlines are closed, with closure ranging from 50 to 150 feet. The presence of Tertiary beds and alluvium deposits prevented the determination as to the closure of several of the remaining structures.

These eighteen structures are situated in a belt ranging from 6 to 12 miles wide and 60 miles long. The most important structures are shown on Plate I by numbers 9-11 and 13-23. Plates II-VI, inclusive, show five of the eight structures known to be closed. These are the Twin Buttes dome, Chalk Creek dome, Elkader anticline, Hell Creek anticline, and Alanthus anticline. Their positions on Plate I are represented by numbers 9, 13, 16, 17 and 22.

The structure maps show the details upon which the contours were based.

Dip readings were taken on beds of chalk and iron bands in the Niobrara but no level lines were run on any beds. Definite zones can be recognized in the Niobrara but particular beds can not be followed far. The structure contours are presented to show the form and closure of the structures as represented by surface dips and are not drawn on any particular horizon.

It is believed that the subsurface structure in western Kansas is likely to be analogous to that of the Eldorado, Kansas, field recently described by Fath⁵, in that the buried structures are much more pronounced than the structural condition at the surface indicate. For example, in the Shumway Dome the structure contours on the outcropping Ft. Riley limestone show a closure of about 30 feet, whereas in the same area the structure developed in the Stapleton oil zone 2500 feet lower shows a closure of approximately 130 feet. The same is true in the Cushing (Oklahoma) field described by Beal⁶

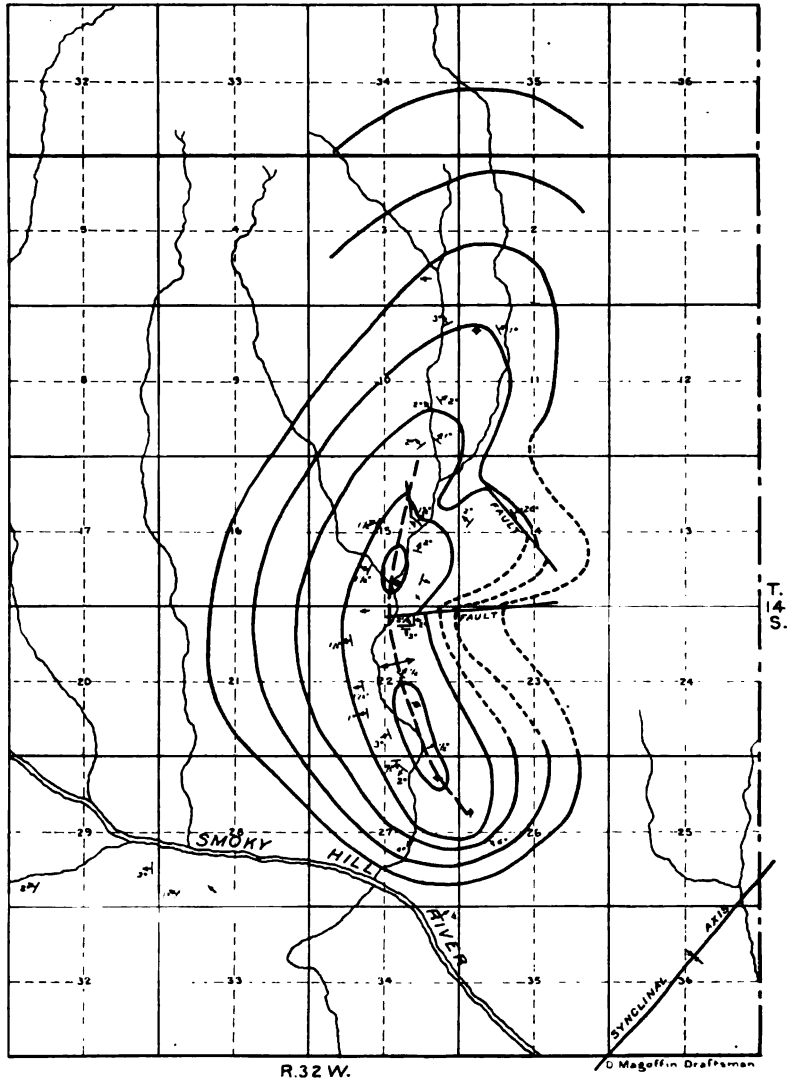
⁵Fath, A. E. *Geology of the Eldorado Oil and Gas Field, Butler County, Kansas*. State Geological Survey of Kansas Bull. 7, Plate XIV, 1922.

⁶Beal, C. H. *Geologic Structure in the Cushing Oil and Gas Field, Okla., and its Relation to the Oil, Gas and Water*. U. S. Geol. Survey Bull. 658, pp. 21-35, 1917.

ELKADER DOME LOGAN COUNTY, KANSAS

CONTOURS SKETCHED ON DIPS
INTERVAL 25 FEET

WALLACE LEE, GEOLOGIST.



Y- Dip and strike of beds

• Flat beds.

▲ Beds flat in direction of strike

Plate IV

Fath⁷ compiled data from Beal's contour map of four domes in the Cushing field, namely, Dropright, Drumright, Mt. Pleasant and Shamrock domes, which show that structures in beds 2550 feet beneath the surface have closures three to four times greater than the surface beds indicate. A study of the contour map of the Eldorado field (Plate XIV) also shows that the tops of buried domes are in nearly every case directly under tops of the domes represented at the surface.

MID-CONTINENT STRUCTURAL PROVINCE

The anticlines and domes present in western Kansas are believed to lie in the mid-continent structural province, where slight closures or even noses and structural terraces are sufficient to trap the oil. The area described in this report is situated between 240 and 300 miles from the Front Range of the Rocky Mountains to the west. A broad arch with its "high" near the northwest corner of Oklahoma and two corresponding synclines trend north and slightly east, thus separating this area from the Rocky Mountains.

FAULTS

Faults are very numerous, especially where structures are developed. The throw of these faults ranges up to 150 feet or more. Most of the faults are of the dip variety, or, in other words, they trend normal to the strike of the beds. Practically all of the faults belong to the normal type.

Where the throw is small, such as a few inches up to a few feet, the displacement may be caused by the readjustment of the brittle Niobrara chalk over the Benton shale, which may be folded without faulting, but when the faults have a considerable displacement it is believed that the faults are deep seated and probably are due to the rejuvenation of old deep seated faults or folds. The presence of oil in the Collyer well (Plate I, No. 6) in the northwest corner of Trego County confirms this theory. Oil in this well was encountered in a bed of sandstone in the Permian Red Beds. There is no

⁷Fath, A. E. The Origin of the Faults, Anticlines and Buried "Granite Ridge" of the Northern Part of the Mid-Continent Oil and Gas Field. U. S. Geol. Survey, Prof. Paper 128C, p. 82, 1920.

known source of oil in the Permian beds in this region, hence it is believed that the oil must have come from below or above. It seems doubtful if this oil migrated downward with the sandstones above containing water and no oil, hence it seems reasonable to assume that it migrated upward from the under-

**ALANTHUS DOME
GOVE COUNTY, KANSAS**

CONTOURS SKETCHED ON DIPS
INTERVAL 50 FEET
FAULTS

L. R. VAN BURGH, GEOLOGIST.

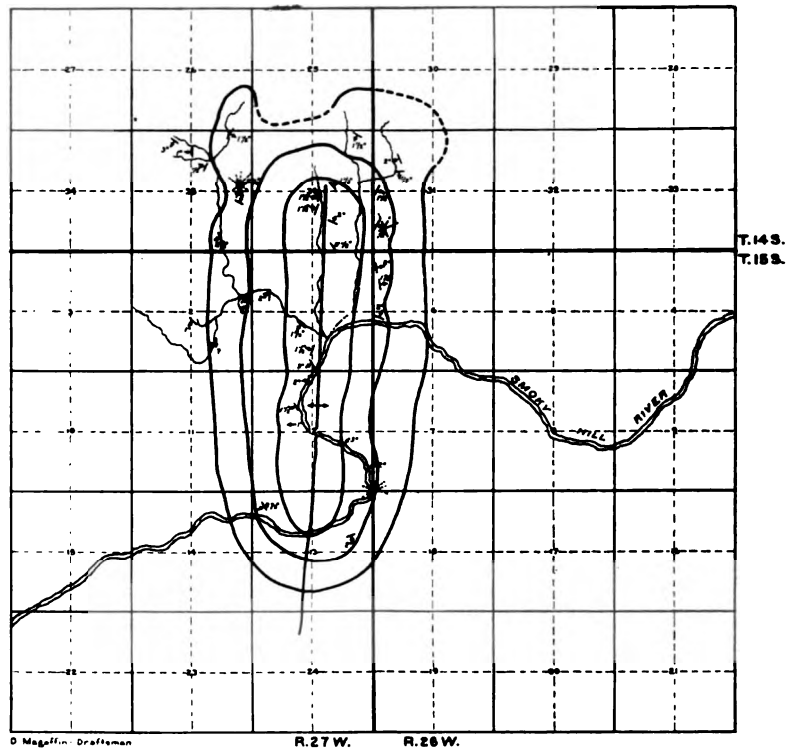


Plate V.

lying Pennsylvanian through numerous major faults which cut the structure near the well.

Many of the faults in the region are filled with calcite, showing plainly the imprints of the slickensided surfaces of the walls. Some of the faults contain a black gouge material

which, when tested for oil with ether, shows a brownish, greasy residue having an odor of vaseline.

IMPORTANCE OF FAULTING

Deep seated faults are of the utmost importance in an area like western Kansas, where the structures are underlain by beds of Pennsylvanian and Mississippian age rich in oil farming materials. The faulting not only permits a greater accumulation by fracturing the sandstone beds and facilitating the migration of oil into them, but also permits oil to migrate upward into reservoirs in the Permian and higher beds, as evidenced by conditions in the Collyer well. It is possible that sands as high in the section as the Dakota may be fully saturated with oil which has migrated from the Pennsylvanian and lower beds.

EVIDENCES OF OIL

The gouge material in fault planes indicates that some oil has come up through these breaks. The Collyer well (Plate I, No. 6) situated in the northwest corner of Trego County on Saline River encountered the largest amount of oil yet found in western Kansas. At a depth of about 1850 feet a sand containing oil was encountered in the Permian Red Beds. Although there were several feet of cavings in the hole and about 1000 feet of water, yet at least 300 feet of oil accumulated on top of the water in a 10-inch casing. The oil has a gravity of 36-37 degrees Baume as determined in the laboratory of the Midwest Refining Company. Practical oil men are of the opinion that this will be a commercial well when the water is cased off and the hole cleaned out and drilled a little deeper. Nothing has been done toward completing the well since encountering the oil, due to a reported controversy over acreage by various interested local groups.

Oil is reported in a shallow well near Athol in Smith County, Kansas, about 65 miles northeast of the Collyer well.

In the Garden City well (Plate I, No. 2) oil was encountered in small amounts in the Cheyenne formation of the Comanchean and also in a sand about 800 feet down in the Permian. It is reported that this well, which is still unfinished, has about 40 feet of oil in it. The structure at Garden City has a

closure of about 30 feet, as determined by surface dips.

Oil is reported in shallow wells along Republican River in Franklin and Harlan counties in southern Nebraska. Oil from these shallow wells comes out of the Niobrara and Pierre shales with water. The oil is transparent and ranges in color from yellowish white to cherry. Some of it is reported to contain as high as 50 percent gasoline.

DEVELOPMENT

Several wells have been drilled in the area and in nearby localities. The location of these wells and the location of the structures mapped in the area are shown by numbers on Plate I.

No. 1 is the Plateau Oil Corporation well in Sec. 27, T. 15 S., R. 31 W., on the Hell Creek Anticline.

No. 2 is the Garden City well in Sec. 35, T. 21 S., R. 31 W.

No. 3 is the Utica well in Sec. 1, T. 17 S., R. 26 W.

No. 4 is the Vesper well in Sec. 10, T. 12 S., R. 9 W.

No. 5 is the Red Cloud well drilled on the north edge of the town.

No. 6 is the Collyer well in Sec. 5, T. 11 S., R. 25 W.

No. 7 is the Chappell well in Sec. 6, T. 14 S., R. 34 W.

No. 8 is the Wray wells, the deeper one in Sec. 14, T. 2 S., R. 43 W.

No. 9 is the Twin Buttes anticline.

Nos. 10 and 11 are two unclosed structures.

No. 12 is the structure on which the Chappell well is drilling.

No. 13 is the Chalk Creek Dome.

Nos. 14 and 15 are unclosed structures.

No. 16 is the Elkader Dome.

No. 17 is the Hell Creek structure.

No. 18 is Hell Creek extension.

No. 19 is an unclosed structure.

No. 20 is Little Dome.

No. 21 is an unclosed structure.

No. 22 is Alanthus Dome.

No. 23 is Alanthus extension.

No. 24 is Liberal well.

The Plateau well on the Hell Creek structure has reached the depth of 2658 feet and has almost reached the first thick salt in the Red Beds. No oil has been encountered. It will be drilled deeper to test the upper sands of the Pennsylvania. It started in the upper part of the Niobrara. The Garden City well was drilled to a depth of approximately 2280 feet and stopped in the Permian Red Beds. Shows of oil were reported in the sands of the Cheyenne and in the Permian. It started near the base of the Niobrara. The Utica well was drilled to a depth of 2700 feet, stopping in the lower part

closure of about 30 feet, as determined by surface dip.

~~Oil is reported in shells~~

the Permian Red Beds. The Vesper well was drilled 120 miles east of the area and is the closest well drilled through Mississippian. So far as known it was not located on structure. It was drilled to a depth of approximately 3600 feet and stopped in the Mississippian. Several shows of oil were reported in the Permian Red Beds. It started almost immediately below the Dakota. The Red Cloud well in southern Nebraska started in the lower part of the Niobrara and drilled to a depth of 3460 feet. A well was also drilled at Red Cloud, about 18 miles west of Red Cloud. This well started in the upper part of the Niobrara and stopped at approximately 1600 feet. The Collyer well started in the upper part of the Niobrara and drilled to a depth of about 1860 feet, where a considerable quantity of oil was encountered in a zone in the Permian Red Beds. The Chappell well started in the Niobrara and at the last report was down 1400 feet. Three wells were drilled near Wray, Colorado, starting in the Pierre. The first was drilled 3650 feet and struck gas in the Niobrara at 1490 feet and a show of oil at 2430, possibly in the Dakota. The other two wells were drilled to 1590 and 1607 feet, where each encountered over a million cubic feet of gas in the Niobrara. One of these wells was being deepened at the last report. Gas is also reported in a well near Liberal, Kansas.

The Plateau well is located on a well developed structure giving 150 feet of closure. The Garden City well is located on a structure which was not examined by the writers but is believed to have a closure of 30 feet. The Utica well is not believed to be located on a favorable structure. Nothing is known by the writers about the structural conditions at the well or that at Red Cloud. The Riverton well is located on a slight anticlinal fold. Whether the fold is closed or not cannot be determined. The area around the Collyer well was not examined by the writers but the well has been reported to be located on structure, much faulted. The Wray gas wells were visited by the writers but no examination was made and no favorable structure was noticed, the area being greatly covered by Tertiary and alluvium.

POSSIBLE SOURCE OF OIL

It is possible to penetrate the upper 1000 feet of the Pennsylvanian by drill holes 4000 feet deep, and all of the Pennsylvanian and part of the Mississippian by a 5000 foot hole, if the section corresponds to the Vesper log.

It is well known that the main source of oil in the Mid-Continent region is in the Pennsylvanian and Mississippian. It is probable that this same condition holds for western Kansas.

The beds of Permian age in this region constitute a poor source of oil but they contain sands capable of serving as good reservoirs for oil coming up from lower formations.

The Kiowa shale in the upper part of the Comanchean may be a source of oil, as it is black and is rich in carbonaceous material.

SUMMARY

The productive oil fields of Kansas are limited to the southeast one-sixth of the state. The western half of the state to date has no proven commercial oil well, although the Collyer well in the northwest corner of Trego County may prove to be one.

The surface rocks in western Kansas are mainly of Tertiary age. Wherever the veneer of Tertiary beds has been eroded through, Pierre shale and Niobrara chalk are exposed, the former, however, only in small areas.

The best exposures of Cretaceous beds are present in a belt 6 to 12 miles wide and 60 miles long in Logan and Gove counties in the valley of Smoky Hill River. In this particular belt 18 structures are developed on the broad gentle arch which connects with the Black Hills. Eight of these structures are known to be closed and some of the others may be, as in some cases their ends are covered with Tertiary beds and alluvium. The closures of the closed structures vary from 50 to 150 feet.

Faults are numerous and many are believed to be deep seated, thus permitting oil if present to migrate upward from the Pennsylvanian and Mississippian beds, which are believed to be the main source of oil in the region. The presence of

oil in the Permian on the Collyer well on a much faulted structure strongly suggests that this oil came up through faults from the Pennsylvanian or lower beds.

Holes drilled to a depth of 4000 feet would penetrate about 1000 feet into the Pennsylvanian in practically all of the structures in case oil was not found at shallower depths.

The writers believe the area lies well inside the mid-continent structural province where slight closures trap and hold oil, and that the conditions here will be found to be similar to Eldorado, Kansas, and Cushing, Oklahoma, in that more pronounced structures will be found in the Permian and Pennsylvanian than the surface beds indicate, and that these sub-surface structures will be found directly beneath the surface structures.

In such a region as western Kansas, (1) where well closed domes and anticlines are developed, (2) where indications of numerous deep seated faults are present, (3) where a rich source of oil is buried within reach of the drill, and (4) where a little oil already has been found, it seems reasonable to expect more oil will be encountered in further drilling in favorable localities.

DISCUSSION

SIDNEY POWERS: The statement is frequently made that oil found in "red beds" has migrated from non-red sediments. As petroleum exploration progresses, more and more oil is found in the "red beds," where it is not supposed to be native and distillation of red shales is said to have yielded oil. It therefore seems necessary to admit that oil may originate in red beds. Moreover, sediments of red color may be deposited under terrestrial, lacustrine and marine conditions and aridity is a common yet not an essential climatic condition. Until more is learned regarding "red beds" it is not safe to condemn any of them as an original source of oil, merely because of the red color.

CHARLES T. KIRK: (1) Answering Becker's question to Powers as to whether there is any bituminous matter reported from the Permian of the Midcontinent: The Delaware limestone of southeastern New Mexico is quite well filled in places with oleaginous matter and has a bituminous odor when freshly exposed.

(2) The principal speaker in selecting Eldorado, Kansas, appears to have taken a special instance where the sub-surface doming is directly under that on the surface. Notable examples exist of production considerably to the west of the surface axis, as in the Sallyards region of the

Flint Hills in western Greenwood and eastern Butler counties, Kansas, and in the Urschel pool. Both these areas are not far removed from the region where Mr. Lupton appears to predict production immediately under the surface anticlines.

W. E. WRATHER: There is considerable evidence locally of the presence of organic material in the midst of the Red Beds. On the northwest side of the Wichita Mountains near Granite Oklahoma, dark colored oil shales appear interstratified with typical red beds. These shales may be seen in the banks of a creek northwest of Granite. The individual strata are seldom more than a few inches thick. Although I know of no analyses having been made, there seems to be a high percentage of bituminous matter present.

WARNER NEWBY: A sample of shale taken a few miles south of Electra Texas, from just below the Beaverburk Limestone of the Wichita Formation was analyzed and found to contain three-fourths of one per cent of carbon. Shales of this character are fairly common in the Wichita Formation and I see no reason why they could not be the source of most of the oil obtained from it.

F. G. CLAPP: Besides the evidences mentioned by Mr. Lupton, other evidences exist that the Carboniferous is likely to be productive under portions of western Kansas, western Nebraska, northwestern Oklahoma and eastern Colorado. These evidences consist, first, of the fact that the Permian series of western Kansas and western Oklahoma does not appear to have been a source of oil, but that the oil has apparently been derived from its upward migration from the underlying Pennsylvanian rocks; hence the showings of oil in wells of the Permian in western Kansas may indicate greater deposits in the Pennsylvanian of those regions. Secondly, oil wells of great volume have been struck in the Soap Creek dome in Big Horn County of southern Montana; and these, when considered in connection with the Permian production in the vicinity of Lander, Wyoming, and Hamilton dome in the same state, prove the existence of great resources of oil, hitherto unsuspected, in the Carboniferous rocks of the northwestern United States. Since the Carboniferous is highly productive in eastern Kansas and also in southern Montana, there seems to be no particular reason why, the rocks of the same series in the intervening region are not likely also to be productive.

WALLACE E. PRATT: Is the gas at Amarillo necessarily Pennsylvanian, as Mr. Clapp appears to suggest? So far as my information goes, there is no proof of the presence of Pennsylvanian beds at Amarillo. There are organic shales and limestones in the known Permian beds at Amarillo. There are hundreds of feet of black shales beneath the gas-bearing limestone at Amarillo, which have not been shown to be Pennsylvanian so far as I know, and which lithologically resemble closely the known Permian section elsewhere in Texas.

There is oil in known Permian rocks of organic character in southwest

Texas. This oil may be shown clearly to be of Permian origin. There is oil in Permian rocks in Mitchell County, Texas, much closer to the Amarillo field. I know of no reason to assign this oil to a source other than the series in which it occurs.

Why then, if oil and gas occur originally in Permian beds in Texas should we assume other than a Permian source for oil or gas in Permian rocks elsewhere in Texas, without definite evidence of such other source?

DR. CHARLES SCHUCHERT discussed briefly the age of the buried formation of western Kansas and the significance of paleogeography.

W. C. KITE: Several geologists, in experimenting with "red beds" shales, have reported the presence of oil, however, it may be as Dr. Schuchert suggests, that these "red beds" are Pennsylvanian and not Permian. To me, the first point of interest is the fact that there is oil in these "red bed" shales and it is of little concern whether they be Pennsylvanian or Permian.

JOHN L. RICH: As has just been pointed out by Professor Schuchert, there are strong reasons for thinking that the Pennsylvanian rocks may be absent from at least part of the area of western Kansas, under discussion.

In northeastern New Mexico a well drilled in 1919 encountered granite immediately beneath the red beds. This well was located on the broad ge-anticline east of the Raton Basin. This broad belt of uplift—a buried granite mountain range of probable late Pennsylvanian or early Permian age—extends northward into Colorado toward the area under discussion. Therefore, the partial or total absence of the Pennsylvanian in that area is a possibility which should not be overlooked.

Inasmuch as the Permian San Andreas formation and its equivalents of New Mexico and Texas is petroliferous, it does not seem necessary to suppose that absence of the Pennsylvanian precludes the possibility of finding oil.

MAX W. BALL: There is no magic in the word Pennsylvanian; no black magic in the word Permian. Oil forming material may be present or have been present in the latter as well as the former. For example, the pre-Cretaceous oil source of Wyoming is, according to Dr. Girty and the U. S. Geological Survey, Permian. This source, which is in the formation variously called Embar, Park City and Phosporia, was formerly considered Pennsylvanian, but fossil evidence obtained during the past few years, chiefly in connection with phosphate investigations in this formation, has led Dr. Girty to conclude that the formation is Permian. Thus, the pre-Cretaceous oil of Wyoming, at least the major part of it, must be considered as of Permian rather than Pennsylvanian origin.

The most persistently saturated pre-Cretaceous sand of Utah is the Moenkopi, which contains both Permian and Triassic formations. This formation has two facies, one red, the other tan. The former is seldom oil saturated; the latter contains some oil at most places where it out-

crops. The red phase contains Triassic forms; the tan phase contains forms of possible Permian affiliation. At most localities the red phase is above, the tan below, and this led for a time to an assumption that the upper part of the formation is Triassic, the lower Permian. Later study, however, discovered localities when the red phase is present at the base as well as the top, and at these localities undoubted Triassic forms were obtained at the bottom of the formation. From the evidence available the entire formation is Triassic. Thus in Utah, as in Wyoming, the principal pre-Cretaceous oil source is post-Pennsylvanian.

E. G. WOODRUFF: There are considerations which cause some of us to view western Kansas with less optimism than Mr. Lupton does. As far as known, the strata which might be expected to produce petroleum in western Kansas were deposited in deep sea marine waters. Formations of this character are not known to produce oil generally. They do not afford vegetable or animal material from which oil is derived and do not embrace sands in which the petroleum can be reservoirized. If there are sands in such deposits the pores are filled with clay or lime rendering the sands non-porous and therefore not fit to serve as reservoirs for liquids.

Thus it seems that in western Kansas there are lacking two essentials for oil fields, namely a source of petroleum and a reservoir body. Wildcatting may find an old granite ridge or hills, but until they are found the region must be viewed with doubt.

CLYDE M. BECKER: The remarks of Mr. Woodruff stir my memory. I cannot but recall the recommendations of ten years ago of the best geological minds relative to the finding of oil in the Red Beds of Oklahoma.

K. C. HEALD: While seeking the rainbow's end in the Paleozoic rocks of western Kansas, the possibilities of oil in the Cretaceous must not be overlooked. The basal beds of the Upper Cretaceous are impregnated with oil in many localities along the Rocky Mountain front, and these same oil-forming conditions may persist far to the east. The chances of oil in the Pierre shale, of Montana age, must also be considered. It is true that the Pierre is not uniformly oil-bearing, but the Florence field of Colorado and the production from the Shannon sand in central Wyoming furnish substantial proof that much oil can come from the Pierre shale in restricted areas. Certainly there is as yet insufficient evidence to justify the statement that such an area does not exist in western Kansas or Nebraska.

DIAMOND DRILLING FOR PRODUCTION

FRANK A. EDSON

The drilling of a 1200 barrel well by the use of the diamond drill, accompanied by the securing of some 85 percent of core and a substantial saving in drilling costs, has been a matter of considerable comment among both operators and geologists. Since the work was done under the actual direction of the writer, he has thought that an account of the operation would be of interest both to members of the Association and to oil men in general.

The well was drilled for the Panuco-Boston Oil Company, a subsidiary of the Atlantic Refining Company. It was located on the Ugarde lease in the Panuco district of Mexico, about 40 kilometers from Tampico. The formation is similar to that found elsewhere in the district. There is about 200 feet of surface soil, mainly river wash, which contains some boulders. Underneath this there are about 1200 feet of shales, presumably Mendez, underlaid by some 700 or 800 feet of the shaly limestone of the San Felipe series. These lie directly upon the Tamosopa limestone, which, however, was not penetrated by the drill as the production was found before this formation was reached. Judged from a drilling standpoint the upper 1400 feet is good rotary ground, although it can be drilled with cable tools. Below this depth the ground is much better for standard than for rotary tools.

The upper part of the formation, down to 1407 feet, was drilled by attaching a fish-tail bit directly to the diamond drill rods by a special bushing and operating as an ordinary rotary. The customary mud-laden fluid was used, an ordinary mud pump being employed for this purpose. The main points of difference between the diamond drill and the rotary in this part of the work was the manner in which the drill stem was rotated, and the way in which it was held in suspension.

The drill stem, or "rods," as they are called in diamond drilling, is directly connected to the engine by bevel gearing very similar in type to that used in the modern gear-driven

rotary. The effect is to give a higher speed of rotation to the bit, the diamond drill ordinarily running from 200 to 400 revolutions per minute, while the rotary normally averages between 60 and 100 revolutions per minute. This higher speed must generate greater centrifugal force, which slaps the mud against the side of the wall somewhat harder than does the ordinary rotary. This is a point which it is probably impossible actually to demonstrate, but rotary drillers with whom the writer has discussed the matter all agree in thinking this to be of practical benefit to the hole.

The drill stem is made up of flush-jointed steel rods, which are of uniform outside diameter. These rods are passed through a chuck, which, while being free to revolve, is attached to a hydraulic cylinder. This cylinder moves vertically either upward or downward, carrying the rods with it. In effect it is a hydraulic jack which carries the weight of the rods and yet allows them to revolve freely. As the water is allowed to escape from the under side of the hydraulic piston the drill stem moves gradually downward, or, if the direction of the flow in the cylinder is reversed, it moves upward. The escape of the water is controlled by a valve and is capable of a very fine adjustment. This method allows the operator both a more positive and a more delicate control of the movement of the drill stem than is enjoyed by the rotary driller. This was well illustrated by a fishing job which occurred at 2100 feet. At that depth the top of the core-barrel, which had been obtained locally and contained defective material, twisted off. A screw tap was attached to the rods, and the engine revolved at the slowest possible speed, while the driller fed the drill stem down so delicately that it entered at the proper speed to firmly thread its way into the inside of the core-barrel. Incidentally the entire operation took only a little over seven hours.

This absolute control of the downward movement of the drill stem enabled the drill to go through gumbo without "balling up." The secret is to feed the bit down evenly and slowly so that it cuts the ground a little more slowly than the pump can take it away. If this is properly done there is no danger of a ball up for there are no cuttings there to ball up.

The value of being able to go through soft ground without being troubled in this way is hard to overestimate.

The cuttings were much finer than those obtained from ordinary rotary drilling. Probably 80 percent would go through a 50 mesh sieve. This is probably due both to the higher speed and the more even feed of the diamond drill. The finer cuttings undoubtedly work farther back into porous strata and thus mud up the hole better. On the other hand they do not afford as much information to either the geologist or the driller. Mr. Elledge, the geologist for the Panuco-Boston, complained that when he washed the samples he had nothing left. When the diamond drill uses the fish-tail bit the log will be even less reliable than the ordinary rotary log because of this fact.

The hole was cased with three lines of casing. For surface conductor 223 feet of 7 $\frac{5}{8}$ -inch pipe was used. Inside of this was placed 548 feet of 6-inch pipe, while the final string was 1407 feet of 4-inch pipe. The casing was all of the ordinary type, no flush-joint being used. The 6-inch pipe was an unnecessary precaution taken because this was the first hole ever drilled in this way. It is being omitted on succeeding holes. The 4-inch pipe was cemented into the lime in the ordinary way by the use of a top and bottom plug. The cementing was done in accordance with the Mexican government regulations, and under its supervision. It is required on all wells drilled in the high pressure areas. In conformity with these regulations the cement was allowed to set for ten days before being drilled out.

In the upper part of the hole difficulty was encountered because the drill stem, 2 $\frac{3}{8}$ inches in outside diameter, was too small for the large size hole which the drill was then making. The side play of the stem caused frequent breakages. This was temporarily remedied by using 4-inch rotary drill stem with only enough diamond drill rods to make the connection through the hydraulic cylinder. Drill stem of a diameter of 3 $\frac{1}{2}$ inches had been ordered from the manufacturers, but had not arrived at the time the writer left Panuco.

Diamond drill rods are ordinarily unscrewed by hand, using a 36-inch pipe wrench, and the machine was not equipped with

mechanical means of breaking joints. This slowed up the operation of coming out or going into the hole, as breaking apart rotary tool-joints by hand is a slow and laborious process. Also the drilling was, perhaps, slowed up somewhat by the fact that the downward pressure of the hydraulic could not be used on the rods without danger of breaking them. This, of course, would only apply to the upper part of the hole. No records were broken so far as an individual day's run was concerned. The average cutting speed with the fish-tail bit was from 10 to 18 feet per hour, depending upon the formation it was working in. It is probable that, with the use of the proper drill stem and the greater familiarity of the crew with the operation, a speed of from 150 to 200 feet per day can be averaged.

After drilling out the cement, work was carried on by the aid of the diamond bit. A $3\frac{5}{8}$ -inch bit, which cuts a 3-inch core, was used. None of the holes in the Panuco district are cased below the top of the lime, so it was unnecessary to carry a larger hole.

A 13-foot core-barrel was used, which necessitated coming out of the hole several times a day. An average speed of approximately 75 feet per day was maintained down to 1850 feet, where enough oil was struck to fill the hole. From there down to 2153 feet, where the hole was bottomed, the drill averaged between 35 and 40 feet per day. The former average was somewhat above the average of cable tools in this district, while they can only make from 8 to 10 feet per day when drilling in a hole full of oil. Lest the Panuco cable tool driller be unjustly criticised, it should be remembered that Panuco crude is of about the consistency of molasses and very effectually cushions the blow of the bit.

A cutting speed of approximately 10 feet per hour was made by the diamond bit. The loss of speed came from the time required in coming out and going back into the hole. At 1500 feet it took about 45 minutes to come out and about 35 minutes to go into the hole. When the hole was full of oil it took nearly two hours to pull out and about the same length of time to go in. A 64-foot steel derrick was used, which allowed the rods to be pulled in 50-foot lengths. The speed of

the drill is governed more by the number of times it is necessary to pull out, and by the length of time required for this operation, than by any other factor. The number of times it is necessary to pull out is governed largely by the length of the core-barrel. A 30-foot core-barrel is to be used on the next hole, and it is very probable that an average speed of between 100 and 125 feet per day will be maintained.

Considerable doubt was expressed as to whether or not the drill would operate satisfactorily when the hole was full of oil, and if the drill stem might not be blown out of the hole when the high pressure was encountered. The oil in the hole seemed to act as a lubricant on the rods, and, if anything, the drill worked more smoothly. On the other hand, while an oil-saver was used when the drill was running, it had to be removed to take the core-barrel out and the derrick and floor became so covered with oil that it was almost impossible for the men to keep their footing. This was the main reason why not over 40 feet was made per day, as the cutting speed of the bit was approximately the same as before.

The high pressure gave no particular trouble except that the last 500 or 600 feet of drill stem had to be snubbed out of the hole with a manila rope. It was unnecessary to use the more elaborate apparatus which had been provided for this purpose. While not over 750 pounds of pressure was encountered the writer has no hesitancy in stating three or four times this amount could have been satisfactorily handled. The secret is never to let the well get away from you.

To the surprise of everyone about 85 per cent of core was obtained. This was due both to the large size of the core and to the flat bedding of the rocks. Probably no one feature of the drilling attracted as much attention as the core. It was a new and satisfactory experience to both operators and geologists to be able to see and handle the rocks which were actually producing the oil. Many of the cores contained fractures which, when broken open, were found to contain drops of oil. Sometimes the gas could be seen bubbling out of the core. As the drill reached greater depths the fractures contained more and more oil, until at about 1850 feet they began to give actual production. The well came in rather grad-

ually from that point until at 2153 feet enough oil was struck to bring the production up to 1200 barrels.

It was observed that these fractures occurred in zones. The drill would penetrate 20 or 30 feet of fractured ground and then go back into solid rock again. This would continue for 50 or 60 feet and then another fracture zone would be encountered. This information would have been very important had it been desirable to shoot the well. The shooter would have known, almost to the inch, just where to put the shot, and could have judged much more accurately as to the amount of explosive required. In general it is hard to overestimate the practical value of the information to be obtained from such cores. The ordinary practical oil operator can obtain more information from them than the trained geologist does now from a microscopic study of well cuttings.

Doubt was also expressed as to whether or not the 4-inch pipe would be large enough to accomodate the oil. As stated above the well came in with 1200 barrels, but the oil coming out of the pipe did not fill more than one-tenth of its area. There may be occasional wells so large that a 4-inch pipe really will not accomodate the oil, but they are few and far between.

An interesting discovery was the fact that the ordinary mud-laden fluid which is used by the rotary can also be used with a diamond bit. It has generally been thought that the latter would require clear water, but about a 20 percent mud solution was used in this hole with satisfactory results. It is probable that even thicker mud could be used if larger waterways were cut in the bit. The fact that mud can be used with a diamond bit makes it possible to drill in caving formations, recover the core, and at the same time hold up the sides of the hole with mud. This makes the diamond drill practicable for softer ground than has been thought before. Just what the limits are in this respect is yet to be worked out.

An equally welcome discovery was the fact that a very considerable saving was made in costs. The hole was completed for less than \$25,000, which is to be contrasted with \$42,500 the contract price at that time in the field. This figure covers the complete cost,—fuel, water, casing, rig, labour,

diamond wear (which amounted to less than one cent per foot), being all included—a “turnkey job” in other words. It should also be remembered that neither the writer nor any of the drillers had ever been in the Panuco field before, so the well was to all intents and purposes a wildcat to them. The writer has no hesitation in stating that as the men become more familiar with the work and develop the technique required in this field the costs will be cut to fifty percent of those of drilling by ordinary methods.

It should be noted that the well was cored all the way through the lime. Had the plugged bit—which is solid and takes no core—been used it is probable that an even greater cut would have been made in the cost of this well. The writer has talked with drillers who have worked in both the Panuco and the Mid-Continent fields. They unite in stating that the rocks in Panuco drill just about the same as the average rocks of the Mid-Continent. He is, therefore, inclined to believe that a very substantial saving can be made in drill costs in the latter as well as in the Mexican fields.

The writer also had charge of a diamond drill in the Southern Fields, which was doing structure drilling. This outfit had just gotten nicely started when he left Mexico, but one observation was made which is of importance to the Mid-Continent operator. The drill was operating in the upper part of the Alezan shales, which are fully as soft as the ordinary rotary ground in this country. Men who have operated in both places say that they are about equivalent to the softer portions of the Redbeds. Yet by taking certain precautions over 95 percent of core was obtained with a single-tube core-barrel. From this experience it is believed that no great difficulty will be encountered in obtaining cores from either the softer shales or sands of the Mid-Continent fields.

NOTE: Discussion of Mr. Edson's paper is included with that on Mr. Longyears article which follows:

THE DIAMOND DRILL IN OIL EXPLORATION

By Robert Davis Longyear

The recent success of the Panuco-Boston Oil Co. in bringing in a 1200-bbl. well with a diamond drill in the Panuco District, Mexico, has aroused the interest of oil men in all parts of the country, and diamond drill manufacturers are receiving an increasingly large number of requests for information on the use of the diamond drill for oil work. In view of this interest it has seemed desirable to submit the following remarks on the general advantages of the diamond drill, substantiated with definite illustrations. The writer is indebted to Lynch Bros., diamond drill contractors of Seattle, to the Diamond Drill Contracting Co., of Spokane, and to E. J. Longyear Co., diamond drill manufacturers and contractors, of Minneapolis, from whose experience most of the data have been obtained.

The details of the bringing in of the Panuco-Boston well are described in a paper prepared for the Seventh Annual Meeting of the American Association of Petroleum Geologists by F. A. Edson, who had charge of the diamond drill work for the Panuco-Boston and Cortez Oil Companies. It will therefore not be described here except to state that this well was drilled to a depth of 2153 feet at a cost, according to Edson, of approximately 60 percent of the price asked by cable tool and rotary contractors in the same district. Elledge¹ has also given a very good description of this well.

The diamond drill can be used for drilling wildcat wells or wells in proven fields either as a distinct outfit or as an interchangeable unit in connection with other methods. It has also a considerable range of usefulness as an aid to geological structure-mapping by drilling shallow holes to determine elevations on key horizons. Although it appears to have been

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¹Elledge, Geo. A., The diamond drill in oil field practice, Oil & Gas Jour., Vol. 20, No. 30, Dec. 23, 1921.

demonstrated that in Mexico the diamond drill can be used in drilling wells in producing fields, yet its chief interest to operators and geologists in the Mid-Continent and other districts of the United States and Canada lies in its adaptability to oil exploration.

LOWER COSTS

The advantage that means the most to the practical oil man is the lower cost of drilling wildcat wells. The diamond drill

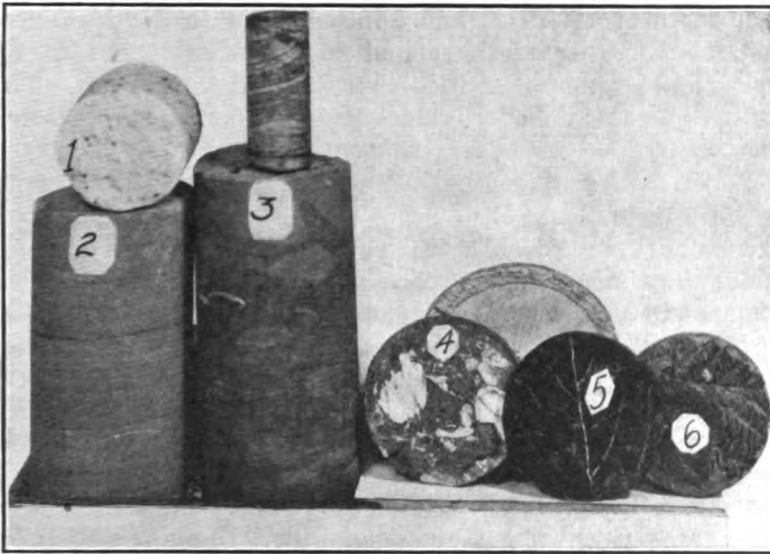


Plate I. Diamond Drill Cores Recovered in Oil Exploration

1. Gas Sand, Shelby, Montana.
2. Fine Sandstone, showing stratification, Kremlin, Montana.
- 3, 4. Fossil Shells, Kremlin, Montana.
- 4, 5. Fossil Leaves, Ferndale, Washington.

secures a lower cost in three ways: (1) Transportation charges are lower because the weight of the outfit is considerably less than the weight of other types. (2) The diamond drill uses fewer strings of casing, thus making a great saving in casing costs. (3) The cost of operation is usually less in wildcatting.

Transportation.—The cost of moving a cable tool or rotary outfit into an out-of-the-way locality is one of the large fac-

tors in the cost of test wells. A cable tool outfit to drill 3500 feet weighs around 250 tons, and a rotary outfit 350 tons. A diamond drill outfit of the same capacity weighs only 60 tons. On a cable tool test in Utah the transportation charges alone amounted to over \$100,000, and other wells in this state have been similarly expensive.

Last year Lynch Bros. shipped a diamond drill outfit into the Peace River District for the British Columbia Provincial Government. This outfit was capable of drilling 3-inch holes to a depth of 1200 feet and 2-inch holes to a depth of 2000 feet. No figures on the actual cost are available, but the writer is informed that the outfit weighed thirty tons. This included sectional boiler, camp, supplies for all winter, drill rods, tools, 1000 feet of 3-inch flush joint casing, and 2000 feet of 2-inch flush joint casing. The outfit was shipped 250 miles by boat from Peace River. and then 26 miles on horse-back over tundra so soaked with water that in places only one hundred pounds could be carried by a horse. Drilling was commenced in 47 days after leaving Peace River. From 700 to 1100 feet has been drilled each month, the highest footage being made in December with the thermometer standing at 45 degrees below zero. It would have been impossible to have taken a standard rig into the site without building a road over the 26 miles of water-soaked tundra. The cost would have been prohibitive.

In the fall of 1920 to a more easily accessible locality in the same district, a standard rig was moved in on sleighs, and up to August, 1921, had drilled a total of only 800 feet. The diamond drill started nine months later, and at the same date had drilled over 2500 feet.

Casing.—The diamond drill uses smaller sizes and fewer strings of casing than the cable tool drill in holes of equal depth. This reduces the cost of a very important item in the expense of a test well. Flows of water do not interfere with the actual operation of the drill and therefore do not have to be cased off until the oil or gas sand is to be tested.

Under-reaming has proved successful with diamond drilling. In one hole now being drilled in the northwest a three inch casing has been under-reamed to date from 160 to 1860

feet, the bottom of the casing being kept within 10 to 20 feet of the bit for the greater part of the distance. Under-reaming is accomplished by means of a special diamond bit that is expanded by the hydraulic pressure of the circulating water. It can be used either by itself at the end of the rods, or in conjunction with the ordinary bit by being coupled to the top of the core barrel.

The sizes of casing selected depend on the depth to be attained and upon the local standard of sizes of the smaller strings of oil well casing. For sizes under 5 3-16-inch it is preferable to use oil well tubing or diamond drill flush joint casing rather than water well casing. The latter is not strong enough for any but the shallower depths. The smaller sizes of flush joint casing listed by the oil supply houses are not strong enough to trust beyond a depth of 1100 or 1200 feet. The flush joint casing used by the diamond drill is made of seamless steel tubing, common sizes being 2-inch (O. D. $2\frac{3}{8}$ -inch), 3-inch (O. D. $3\frac{1}{2}$ -inch) and 4-inch (O. D. $4\frac{1}{8}$ -inch). This casing costs more than other kinds, but the life is very much longer. It hangs free in the hole and can therefore be under-reamed and recovered with greater ease. It does not cause such a reduction in the diameter of the hole as outside coupled casing.

Fewer strings of casing are required because in most formations the diamond drill hole does not cave as readily as the cable tool hole, as the bit makes a smooth cut instead of a jagged break. The only abrasion on the walls is the turning of a line of smooth flush-jointed rods, while in the case of the cable tool outfit the cable is continually whipping the loose particles from the walls. In soft formations the diamond drill can use a fish tail bit with mud-laden fluid and keep the walls plastered with mud. Those familiar with the rotary system of drilling appreciate the great value of this method as a means of preventing cave.

A diamond drill is now in operation in Oregon, and to date has drilled an open hole in formation that has required three strings of casing in nearby churn drill holes. The cave is due to squeezing shale. The squeeze is noticeable in the diamond drill hole when the hole stands for any length of time as be-

twen shifts; but it takes only a few minutes to wash through the cave, and the circulating water keeps the hole open while drilling.

Four holes were recently taken over by a diamond drilling contractor for completion after they had been abandoned by a cable tool drill. One of the holes drilled near Ferndale, Washington, started with a diameter of 18 inches and at a depth of 2100 feet had to be cased with a 4-inch casing. The hole was continued with a small string of tools to 2400 feet. At this point it became necessary to under-ream, but the tools were soon lost and could not be recovered. The diamond drill was then installed. A hole was drilled down alongside of the tools and continued to 3603 feet, finishing with a diameter of 2 7-16 inches. Another well was started by cable tools with a diameter of 15½ inches and was reduced to 4 inches at 2026 feet. The diamond drill completed it to 2826 feet, with a diameter of 2 7-16 inches. Another cable tool hole near Pincher Creek, Alberta, had to use so many strings of casing that it was reduced from 15½ inches to 4 inches in 1500. Again the diamond drill took over the hole and completed it to 3000 feet. The fourth hole was started 10 inches in diameter and had to be changed to a diamond drill hole at 700 feet when it had been reduced to 3½ inches in diameter. In spite of the large number of strings of casing used in these four wells, all four of them had fresh or salt water flowing from the inside casing when taken over by the diamond drill.

These instances are mentioned to illustrate the large number of reductions in casing required by the cable tool drill in comparison with the diamond drill. Along with the saving in weight and cost of the casing comes a saving in the expensive tools for handling the casing, such as tongs, spiders, and many other varieties of casing tools.

Cost of Drilling—Aside from the cost of transportation and casing, the cost of diamond drilling the deeper wildcat wells has been on the whole less than the cost of cable tool drilling. Diamond drilling is not subject to the great variations in costs such as are met in wildcat drilling with cable tools. Drilling with the diamond drill is nearly always cheaper than the other

types of drills in the harder formations. The rotary drill will make the greater progress in very soft formations on account of the great weight of the bit. This system, however, is not suited to wildcat work on account of the poor sample and the danger of drilling through an oil horizon without recognizing it. In shallow wells up to 1000 feet, if transportation is not expensive, the portable churn drill can probably drill at less expense than the diamond drill; although it is expected that the manufacturers will materially improve the efficiency of the diamond drill for this type of work, as they gain more experience.

The principal variable factors determining the actual operating cost per foot of a diamond drill exclusive of handling casing and other extra work, are the rate of progress and the diamond wear. The rate of progress in the diamond drill holes drilled to date varies greatly with conditions. The Panuco-Boston well averaged 35 to 40 feet per day of 24 hours even with the hole full of oil. Another diamond drill recently commenced its first hole in Mexico and to date has drilled a 3 $\frac{5}{8}$ -inch hole to a depth of nearly 1200 feet with an average of 66 feet per day of 24 hours, exclusive of time spent in handling and cementing casing, fishing, and other delays. This figure includes all minor delays of less than one tower.

Fishing jobs do not delay the diamond drill as much as the churn drill because the rods give a positive control over the fishing tools that is impossible to attain with a flexible cable. On one hole in Mexico a broken core barrel at the bottom of the hole was fished out with a delay of only seven hours. Less expensive and a less number of fishing tools are kept on hand for diamond drill work.

The other principal factor of diamond drilling cost is the carbon or black diamond wear. A carbon loss of 25 cents per foot is a very high wear for sedimentary formations. In some cases the wear is practically nothing. On the other hand an advertisement of a well known and reliable roller bit for use with the rotary drill cites an instance where the cost in wear of the rollers in certain hard rocks was only \$4.10 per foot; the same advertisement gives very much higher costs for other types of rotary bits. \$4.10 per foot is probably from

five to ten times the wear that would be incurred in drilling the same rocks with a diamond bit of the same diameter.

GEOLOGICAL INFORMATION

Of equal importance to lower costs, and often of greater importance, is the geological information furnished by the diamond drill cores. To the geologist testing a new locality this information is invaluable. There are a large number of structures that have proved productive only after drilling a number of wells. It is undoubtedly true that many supposedly dry structures might have proved productive if the geologist had had diamond drill cores to assist him in the drilling of additional holes. Those who have seen diamond drill cores from oil or gas sands have been surprised at the unsuspected nature of the information given. In the Panuco-Boston well the occurrence of oil in definite fractures was clearly visible, and in some pieces of core the gas was seen to bubble out of the rock. Frederick Stone, in a paper recently read before the Mining Men's Association of Spokane, describes diamond drill cores from a gas sand drilled by him. These cores showed that in this locality the gas flows through cracks and open crevices in the sand rather than through the pore spaces between the sand grains. The sand was first struck near the end of a run with the core barrel nearly full. When the core was removed from the core barrel a strong odor of gas was noticed. After drilling a few inches on the next run the gas began to bubble up through the circulating water, and on pulling the rods one of the gas seams was noticed in the core. From that point on until the drill passed out of the gas sand these seams were noticed at irregular intervals. In another well, cavities in a limestone were seen to be filled with a heavy black oil.

In the state of Washington a hole was drilled with a diamond drill to reach a rather unusual occurrence of gas in basalt. A 3-inch hole was drilled through a "sand" at 750 feet making 650,000 cu. ft. of gas. The hole was then reamed out to 3½ inches and cased with a 3-inch flush joint casing, and then continued to 2212 feet. Another gas horizon was encountered at 1180 feet. By drilling through a stuffing box they were able to utilize the gas for power. The drill cores gave a great deal

of information on the problem of the unusual occurrence of the gas in the basalt. Churn drillers reported that they got more or less gas in porous layers of the basalt all the way down. The diamond drill proved that the gas came from fractures three to fourteen inches wide, filled with broken material. While certain porous beds above the cracks yielded gas, the full flow did not develop until the seams were reached. The well has not yet penetrated the total thickness of the basalt to determine the original source of the gas.

Under certain conditions it is possible to determine the direction of dip of the formation from diamond drill cores. This is accomplished by lowering into the hole a tube containing a small mass compass floating in hot gelatin and letting it set long enough to allow the gelatin to solidify. At the lower end of the case containing the compass is attached an inverted cup containing wax on which an impression of the irregular surface of the bottom of the hole is made. The impression and the compass test are made at the same time. Water channels cut in the compass case permit the washing of the hole clear of all cave before taking the impression. After removing the impression cup and the compass and marking the north point on the wax, a short piece of core is drilled and removed from the bottom of the hole. By orienting the core so that its upper surface coincides with its wax cast it is possible to project the north point on to the core, and thus determine the direction of the dip of the bedding shown in the core. Corrections for the deviation of the hole from the perpendicular can be made by using a glass tube containing hydrofluoric acid in connection with the compass.

It is difficult to estimate the scope and value of the geological information that can be derived from an extensive use of the diamond drill. Geologists familiar with the methods of taking core with the rotary drill can appreciate the advantages that can be gained from a complete sample wherever desired from the surface to the bottom of the hole. Difficulties of correlation can be reduced to a minimum because the log of the well consists not only of the driller's interpretation of the formations, but also of a physical record showing to within a fraction of a foot every change in character. Fossils, porosity,

saturation, fracturing, and other geological phenomena are studied from a scientific point of view with the aid of the diamond drill. The development of the lease depends to such an extent upon these details of subsurface geology that every lease should have diamond drill cores through the oil sand from at least one or two holes.

OTHER ADVANTAGES

Other advantages of the diamond drill besides the above mentioned advantages of lower costs in certain cases and more reliable geological information have been described in other articles². These advantages include the greater ease with which oil or gas under high pressure can be tapped, the greater certainty that the hole will reach the desired depth, and the ability to use the drill as a means of completing holes that have been started by other methods but for various reasons cannot be completed with the original outfit. Illustrations of the latter case have been cited above, where too many strings of casing necessitated abandoning the hole with the cable tools, but where the diamond drill easily continued the hole. In 1919 a standard hole was drilled in Choctaw County, Oklahoma, to a depth of 2200 feet where quartzite was encountered. The progress became too expensive, so a diamond drill was installed and the hole completed with little difficulty to a depth of 4970 feet, with an open hole from 2200 feet to the bottom.

Another common use of the diamond drill is in mapping geological structure by drilling shallow holes to certain key beds. Work of this kind is being carried on in Oklahoma, Kansas, Texas, Illinois, California, and other localities. Such work

²Edson, F. A., Use of the diamond drill in oil fields, *Oil & Gas Jour.*, vol. 19, No. 30, pp. 76-79, Dec. 24, 1920; Drilling oil wells with the diamond drill, *Bull., A. A. P. G.*, Vol. 5, pp 386-393, May-June, 1912; Diamond drilling for production, *A. A. P. G.*, March meeting, 1922.

Danford, M. O., The diamond drill as a wildcat aid, *Pet. Age*, Vol. 7, pp. 73-74, Oct. 1920.

Mitchell, J. S., Prospecting for oil with the diamond drill, *Eng. & Min. Jour.*, Vol. 113, pp. 18-19, Jan. 7, 1922.

Elledge, Geo. A., The diamond drill in oil field practise, *Oil & Gas Jour.*, Vol. 20, p. 82, Dec. 23, 1921.

Fay, Albert H., The diamond drill as an aid to oil prospecting, *Eng. & Min. Jour.*, Vol. 110, pp. 1133-1134, Dec. 11, 1920; reprinted in *Oil & Gas Jour.*, Vol. 19, p. 88, Jan. 7, 1921.

is usually done with a light portable gasoline outfit and the cost per foot is very low.

OBJECTIONS TO THE DIAMOND DRILL

Certain objections have been raised to the use of the diamond drill in oil work, some of them based on fact, and others on a misconception of the nature of diamond drill work. In the first place it is stated by some that the circulating fluid loaded with the cuttings made by the face of the bit will seal off oil and gas sands. The experience to date in the few diamond drill holes that have penetrated oil and gas sands has proved quite the contrary, the oil flowing freely as in Mexico, and the gas flowing in considerable volume as in the hole drilled in basalt in Washington. If the gas is not sealed off in such a case, it will certainly not be sealed off when it occurs under greater pressure. Moreover in drilling an oil sand, the cuttings are sand, not mud, and therefore should have little if any effect on the flow of oil or gas. In any case cores would present definite evidence of the presence of oil and to some extent that of gas. It is generally recognized by petroleum engineers that a virgin oil sand will usually take little water and practically no mud.³

In the second place it is thought by some that a hole drilled with a diamond drill hole is too small, even for a test well. It must be remembered in this connection that the great majority of test wells are dry, and therefore the prime consideration in drilling them is the *most information for the least expense*. Diamond drills can be purchased capable of drilling 4-inch holes 3500 feet and deeper. Since the core shows whether the sands contain oil or not and also shows the porosity, extent of fracturing, and other features, this information alone should suffice. Even for the sake of argument if it is necessary to drill a larger diameter well at the same location, the cost of the original diamond drill hole is a worth while investment from the standpoint of the geological information secured and the assurance of the presence of oil in quantities to warrant drilling the larger holes. But as a matter of fact there is no reason for presuming that the diamond drill hole is not large enough

³Swigart, T. E., and Schwarzenbek, F. X., Petroleum Engineering in the Hewitt Oil Field, U. S. Bureau of Mines in cooperation with the State of Oklahoma and the Ardmore Chamber of Commerce, p. 61, 1921.

for production. The Panuco-Boston well flowed 1200 bbls. per day from a $3\frac{5}{8}$ -inch hole. Even if the well must be pumped, a $3\frac{5}{8}$ or $3\frac{3}{4}$ -inch hole will admit a 3-inch flush joint casing, which in turn will take a 2-inch oil well tubing and working barrel. In deeper holes, say from 3500 to 5000 feet it may be necessary to reduce the diameter to $2\frac{3}{4}$ inches. This hole can be cased with 2-inch flush joint casing which will admit $1\frac{1}{2}$ -inch flush joint tubing and a special $1\frac{1}{8}$ -inch flush joint working barrel. This working barrel may be smaller than desired, but nevertheless the well will be a producer if oil is found in commercial quantities.

There is no necessity, however, of maintaining this small-sized hole. If the last string of casing is not permanently cemented the diamond drill hole may be reamed so as to increase the diameter from 30 to 50 per cent, permitting the use of a larger pump barrel and tubing. It is possible to ream that part of the hole through the producing horizon still larger with an expansion under-reamer, and thus allow greater seepage and more reservoir space around the barrel.

The Federal leasing regulations specify that a six inch hole must be drilled on government leases. This has been a deterring factor operating against diamond drilling in the Rocky Mountain region and Alaska where diamond drilling would save a great expense in transportation. In this connection the following letter written from the office of the Department of the Interior is of interest in showing that the regulations are not to be arbitrarily applied in all cases, and that under certain conditions the Department may see fit to allow a hole of smaller diameter than six inches:

DEPARTMENT OF THE INTERIOR
WASHINGTON

Mr. Dan Sutherland,
Alaskan Delegate,
House of Representatives,
Washington, D. C.

Feb. 11, 1922.

Mr. Dear Mr. Sutherland:—

Referring to the letter from Lynch Brothers dated Jany. 9th, 1922, regarding the use of diamond core drilling in Alaska on Government lands;

The regulations governing prospect work upon Government lands provide that within one year (3 yrs. in Alaska) from a certain date the permittee must drill one or more wells not less than 6 inches in diameter

to a depth of at least 500 feet each, unless valuable deposits of oil and gas are encountered sooner.

It does not seem advisable to change the regulations reducing the diameter of the hole in prospect wells, but I appreciate that there are many cases when diamond drill work would be perfectly satisfactory in order to test out land. It is my belief that in certain cases the Secretary of the Interior will be willing to waive the requirement as to the diameter of the hole provided of course that he is satisfied the work will be carried on in a workmanlike manner and for the purposes of actually testing out the area. Obviously each case must be handled separately and it would be my suggestion for any one wishing to sink diamond core drill holes to meet the requirements of the permit, that they petition the Secretary of the Interior to be granted permission to do so.

Very truly yours,

E. C. FINNEY,

Acting Secretary.

FUTURE FIELD OF USEFULNESS

The extent to which the diamond drill will eventually be used in oil exploration cannot be predicted. A limited field of usefulness is granted by all, but some are hesitant to predict a very wide application without further proof of its value. The proof of its value must come with actual use. Practical results have been cited in this paper which go a long way towards proving its usefulness. Further evidence is desired in different fields; to obtain this evidence someone must be the pioneer. The manufacturers are open minded and willing to cooperate most heartily in the work of adapting the diamond drill to the special conditions and the new demands of oil drilling. Improvements have already been made and more are going to be made. A special oil saver has been designed to permit drilling wells into oil and gas sands under high pressure. One of the manufacturers has designed a complete new drill specially adapted for oil work with double hydraulic feed cylinders of thirty-inch stroke, a sand reel, and a two-cylinder steam engine all in one self-contained unit. Other improvements will follow with increased experience. It is probably safe to predict that the diamond drill will in a short time become the principal drill for wildcat holes. It may not replace to any appreciable extent the cable tool or rotary drill in most proven fields, but will undoubtedly find a wide application as a supplementary device for obtaining geological information to aid in the scientific development of a field.

DISCUSSION

L. E. TROUT: In using the diamond drill in producing fields which have a number of horizons producing gas with heavy pressures, say from 400 to 1000 pounds to the square inch, is it possible to mud off these sands successfully or must a new string of casing be set in each case in order to reach a deeper oil producing stratum?

F. A. EDSON: Any sand which can be mudded off by the rotary can be mudded off in the same way by the diamond drill, for the diamond drill can use the same fluid as the rotary. In case the gas pressure is greater than the hydrostatic pressure of the fluid in the hole the California system of mudding under pressure can be used successfully. In any event the diamond drill is under no greater handicap than either of the other methods.

JOHN L. RICH: It seems to me that we as Petroleum Geologists should do all that is possible to further the introduction of diamond drilling because the information to be obtained from cores promises to solve many of the scientific problems of petroleum geology which cannot be solved on the basis of the data obtained from the cuttings of the churn drill. Many of these problems have the greatest practical interest. Among others may be mentioned the problem of the so called dry sands of the Appalachian and Kansas fields, and the problem of the significance of fractures as oil reservoirs. The value of cores in settling problems of stratigraphy and correlation is of course obvious.

DAVID WHITE: The increased interest on the part of oil geologists and of the companies in prospecting with the core drill has a very favorable bearing on the search for potash in West Texas long carried on by the U. S. Geological Survey in cooperation with the Texas University Bureau of Economic Geology and Technology. As most of you know, the logs of wells and analyses of cuttings from several of the wells drilled in the region embracing the southern end of the Staked Plains indicate the probable presence of potash in the form of polyhalite in commercial amounts. Nevertheless the exact thickness and the degree of purity of the deposits can not be satisfactorily determined until cores are cut through the potash-bearing zones, which are now known to be rather numerous. Accordingly it is greatly hoped that those oil geologists who have to advise companies regarding drilling in the southern portion of the region of salt deposition, embracing an area of about 125 miles east and west and 75 miles north and south, as shown on a map published in a paper by myself in April by the A. I. M. & M. E., will arrange so far as practicable for cutting cores through the enormously thick salines underlying portions of this region. At least, arrangements should be made for frequent bailing with saving of cuttings and possibly for the use of saturated brines where the churn drill is employed.

JOHN R. SUMAN: With reference to the use of diamond drill equip-

ment in territory where conditions are similar to those in the fields of Southern Mexico I would offer the following criticism. I have been reliably informed by competent engineers working in the fields of Southern Mexico (Amatlan, Zacamixtle, Toteco, etc) that the gas pressures encountered are greater than the pressure of a column of mud-laden fluid of a height equal to the depth of the hole. For this reason all wells drilled in this territory with rotary drilling equipment have given more or less trouble and some very serious and disastrous accidents have arisen from these attempts to drill into the lime with machinery of this type. It is impossible, with the equipment now in use, to prevent these blowouts and once they start it is impossible to bring the well under control until a vast amount of damage has been done. Operations being carried on with a diamond drilling outfit would be even more susceptible to these troubles than the standard rotary drilling equipment owing to the fact that the ordinary rotary drills use a much heavier mud than the diamond drilling outfit. Furthermore, a standard rotary drilling outfit usually has better tools and appliances at hand for combatting blowout evils than the ordinary diamond drilling outfit.

With reference to the matter of taking cores it might be of interest to those members of the Association who are not up-to-date with present practice in the Gulf Coast fields to know that some very fine work is being done down there in the taking of cores in the drilling of wells with the standard rotary drilling equipment. The taking of cores, both in hard and soft formations, has been developed to the point where almost all the drillers are adept at the work and cores are taken with little or no trouble from wells up to 5000 feet deep. All the larger companies are coring very extensively in their drilling operations and some interesting information as to the character of the producing formations is being obtained. These cores not only show the extent and general character of the producing sands but fossils are being found both microscopic (foraminifera) and megascopic. By the use of these fossils it is possible to correlate the sands as to age in a much more satisfactory manner than has been possible heretofore. The coring devices used in this work have also been perfected to a very high degree. One ingenious operator has perfected a core-barrel which remains absolutely closed until it gets to the bottom of the hole and starts to rotate. It also closes immediately when the driller starts to remove the drill stem thus making it possible to get cores of the very softest sands and muds. This is quite an improvement over the basket-type of core barrel commonly used which has to be rotated with the full weight of the drill stem on it in order to effect closure. This rotating under pressure generates an enormous amount of heat which quite often melts the core into a slag.

It is my impression that in drilling in the soft and caving formations of the Gulf Coastal fields diamond core drilling has very little to offer by way of improvement over the standard rotary drilling methods now in use by the better class of operators.

THE PETROLEUM GEOLOGY OF A PART OF THE WEST-
ERN PEACE RIVER DISTRICT, BRITISH
COLUMBIA

BY EDMUND M. SPIEKER

INTRODUCTION

The attention of those interested in the petroleum resources of North America has in recent years been turned with some keenness of anticipation towards the belt of moderately folded rocks lying between the Canadian Rocky Mountains and the plains. Between the international boundary, at latitude 49° N., and the northern boundary of British Columbia, at latitude 60° N., lies a strip of territory, fronting the Rocky Mountains, that is underlain by a succession of Cretaceous rocks which may somewhere contain commercially valuable accumulations of petroleum. The stratigraphic section is favorable, good structure is plentiful, and a few scattered seepages indicate the presence of petroleum at least locally. The inaccessibility of most of the area has held back development, but in recent years a small amount of geologic work has been done, and drilling has been started at two accessible localities. By far most of the area is a wilderness into which none but the trapper and occasional explorer has penetrated.

During the summer of 1920 the writer, assisted by W. R. Smith, examined in reconnaissance a part of the belt in northeastern British Columbia south of Peace River, and this paper is intended to present briefly the results obtained. The work was done for the Department of Lands of the provincial government of British Columbia, and a report was published as a serial pamphlet of that department in 1921, but that publication does not normally find its way to the geologic public, and the writer has prepared this paper in order that those interested in the region may have the benefit of his observations.

The writer wishes to express acknowledgment to Dr. F. H. McLearn, of the Geological Survey of Canada, for advice and

Introduced by K. C. Heald.

criticism given in the field and office; to Professor Edward W. Berry, of the John Hopkins University, for the determination of fossil plants and for general criticism; to Dr. T. W. Stanton, of the United States Geological Survey, for advice concerning the invertebrates collected, and to the Department of Lands of British Columbia for permission to publish this paper.

Beyond those areas directly adjacent to surveyed land-lines no mapping of much worth had been done in the region, and the accompanying map is largely based on pace traverses carried along all of the routes taken by the writer's party.

LOCATION AND GENERAL CHARACTER OF THE REGION

- The region described in this report lies to the south of Peace River, extending as a belt 10 to 40 miles wide from Hudson Hope southeasterly to Murray River at the mouth of Flat Creek. This area forms physiographically a transition zone between the more abrupt foot-hills and the gently rolling plains; the topography is varied, and in places sharply sloped hills break the rolling nature of the terrane, but as a whole the belt is decidedly less precipitous than the foothills.

The region is drained by Peace River and its tributaries. The portion drained by small direct tributaries of the Peace extends from Hudson Hope to the divide north of Moberly Lake. Adjoining this to the south is a belt occupied by Moberly River and its tributaries, which is about 10 miles wide and extends the width of the belt in an east-west direction. The major portion of the area is drained by the Pine River system, the three main branches of which have cut deep valleys across it.

Peace River occupies a valley about 800 feet deep, which in the vicinity of Hudson Hope is from 2 to 3 miles wide. The upper levels of land adjacent to the valley are more or less flat-lying, but 7 miles to the south hills break the evenness of the plateau, and from the general neighborhood of Moberly Lake southeastward over the entire area the topography is broken by hills and the deep valleys of the Pine River drainage.

The valley of Moberly River, which is occupied south of Hudson Hope by Moberly Lake, is from 1 to 2½ miles wide. In the region studied its valley is U-shaped, with many flats

and a meandering stream-bed. It offers no serious difficulty to travel; roads might be cut along it at no great expense.

Pine River flows from Falls Creek to the mouth of Wabi Creek in a deep, U-shaped valley which was undoubtedly the pre-glacial course of the stream. Below Centurian Creek the present bed of the river is post-glacial, the extensive morainic deposits threabout having deflected its waters south-eastward to cut the existing V-shaped gorge through the St. John shales. The old course of the Pine is now occupied by Centurian Creek; it is a broad valley filled with glacial material, in which are many kettles and lakes of glacial origin, and it is clearly discernible from the hills west of Centurian Creek as the course formerly followed by the Pine directly northeastward to the Peace. At the Middle Forks the Pine enters the pre-glacial course of Sukunka River.

Sukunka River is the central member of the Pine River system. It is somewhat larger in volume of water than Pine River. Its valley varies in width from 1 to 3 miles in its lower part and does not narrow appreciably as far as can be seen from the hills at the mouth of Burnt River. For a distance of about 22 miles from its mouth the valley is heavily forested with poplar, willow, and spruce. Above this stretch the timber has been burned, leaving the country bare and open as far as the bend above the mouth of Burnt River.

Murray (East Pine) River is the easternmost and largest of the three main branches of Pine River. Its valley differs somewhat from those of the Sukunka and Pine. Physiographically it is infantile, having long stretches of V-shaped channel, with almost continuous cut-banks of shale and sandstone forming its sides, and in places the stream flows in a true box canyon. The Murray presents a profusion of rock-exposures at the river's edge throughout its length in the area, whereas the other rivers named, occupying more mature valleys, show few cut-banks and expose the more resistant beds only in the upper reaches of their valley-sides. The Murray Valley is heavily timbered, but the timber is small and has accordingly no present commercial value.

The two larger lakes in the area, Moberly Lake and Gwillim Lake, are of common origin, each having been formed through the damming of its parent stream by glacial material. In each case the localization of the morainic material was undoubtedly determined by the presence at the surface of the resistant sandstones of the Dunvegan formation. The major parts of these two lakes, and of Moose Lake as well, occupy beds cut in the St. John shale, but at the east ends of the lakes the overlying Dunvegan formation is brought to water-level by east dips, and its presence there undoubtedly determined the placing of the dams which caused the lakes. It is interesting that the geologic conditions surrounding these lakes are identical.

The entire area is generally well forested with young spruce, pine, poplar, willow, and alder. Localities which are not largely forest are rare. As a rule the northern banks of the rivers have less vegetation, particularly of the forest type, than the southern banks. The dense undergrowth in the forest, together with scattered areas of fallen timber and muskeg, make travel in this country very difficult except on those trails which are kept clear by the Indians for their hunting and trapping. The geologist who plans to work in northwest Canada should be prepared to face these obstacles, and in addition should be willing to endure unparalleled clouds of mosquitoes, black flies, and "bulldog" or horse flies.

With the exception of a few localities on Pine River, there is little or no timber of commercial value in the area. Above Peavine Flat on Pine River are flats on which spruce as large as 30 inches in diameter is growing. Elsewhere, with the possible exception of a small area on the divide between Marten Creek and Rocky Mountain Lake, the writer observed no timber of commercial value.

STRATIGRAPHY

The formations exposed in the region here described range in age from Triassic to Upper Cretaceous. A general review of the entire succession is given in the following table of formations.

Table of Formations

System	Group	Formation	Character	Thickness (in feet)
Upper Cretaceous	Colorado	Sukunka member	Coarse subareal sandstone, hardened calcareous muds, green shale, lignite	1,000 +
		Dunvegan	Massive to thin-bedded sand- stone, varying in origin from lit- toral to subaereal, with some shale and few thin seams of lignite.	1,000 +
		St. John	Black marine shale, usually arenaceous, with intercalated sandstone and marine sandstone locally	1,400-2,200
Lower Cre- taceous	Kootenay	Bullhead Mountain	Hard green-grey conglomerate, coarse-grained, massive sand- stone and shale with beds of high- grade coal	1,500-3,000
Jurassic (?)		Pine River...	Blue-black marine shale with intercalated limestone and some sandstone	300 + (base not exposed)
Triassic	Upper Triassic	Schooler Creek	Purple and grey limestone. and fine-grained sandstone; lime- stone vesicular near top.	2600 +

The preliminary results of work by F. H. McLearn on Peace and Smoky Rivers, where the whole section is exposed, will be found in Part C of the Summary Reports of the Geological Survey of Canada for 1917 and 1918.

Triassic—Rocks of Triassic age do not outcrop in the area here described, but inasmuch as they would probably be penetrated by a borehole on the Pine River anticline, some mention of such information as exists concerning them is pertinent.

On Peace River, above the Rock Mountain portage, McLearn¹ has found the Triassic series to consist of dark-purple lime-

¹McLearn, F. H., Mesozoic of Upper Peace River, B. C., Geol. Surv. Can. Summary Rept. Part B, 1920, pp. 2B, 3B.

stones and hardened, fine-grained sandstones with *Pseudomonotis subcircularis* Gabb, and many ammonites. These beds are probably all of marine origin. The sandstone of the Peace

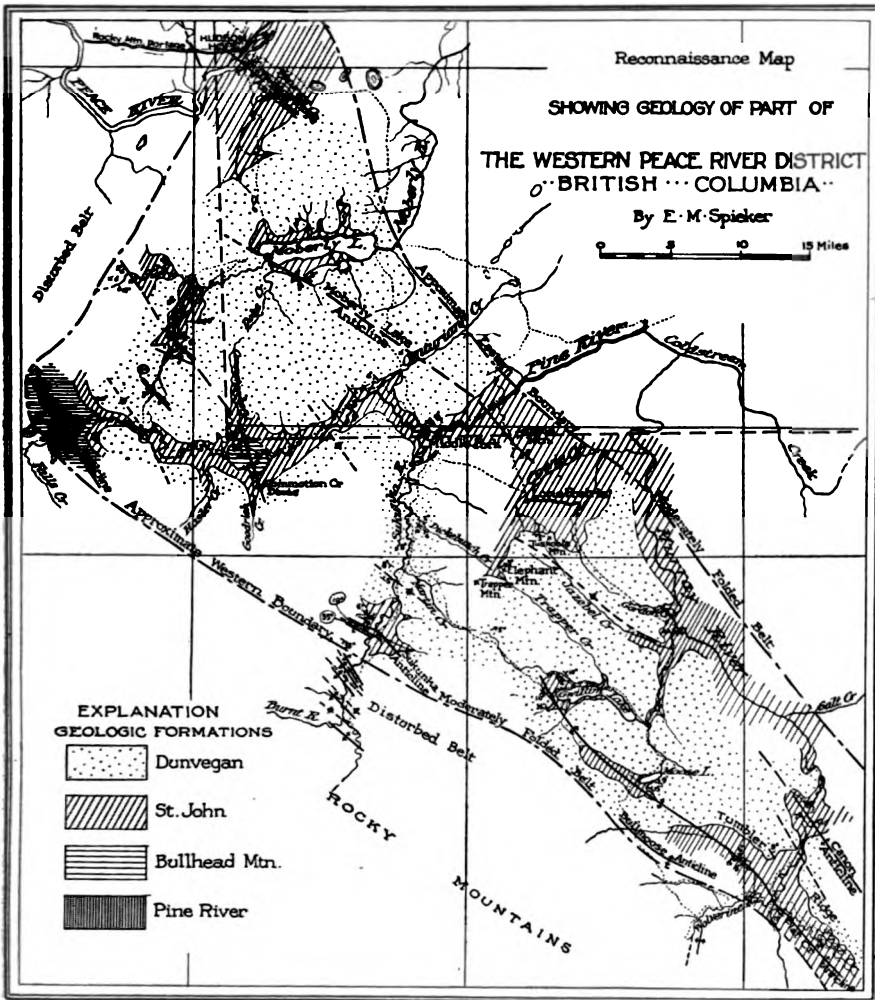


Plate I.

River section is firmly cemented with calcium carbonate, and its general appearance does not indicate that it might make good reservoir rock. However, in the area here considered the

beds have undergone less metamorphism than on the Peace, and the sandstones may be more porous.

Pine River Formation.—This formation is the lowest of the series exposed within the area examined. It occurs at the surface on the crest of the Pine River anticline, being exposed in the narrow valley of Crassier Creek for a distance of about 4 miles above its mouth. It consists chiefly of firm blue-black clay shale, the lowest observable beds of which are remarkably pure, being almost entirely free from sand and presenting the appearance of a hardened, uncontaminated black clay. In this respect it differs from most other marine black shales of the general region, which are almost uniformly sandy. Interspersed with the shale are bands of limestone and sandstone in thicknesses from a few inches up to 20 feet or more; the limestone is very compact and hard, steel-grey on fresh fracture, and, varying with changes in purity, weathers into shapes ranging from angular to gnarled or rounded in outline. The color of its weathered surface is greyish-yellow. No fossils were found in the limestone at any of the exposures visited by the writer.

The section of the Pine River formation exposed in Pass Creek is as follows:

<i>Section of the Pine River formation in Pass Creek</i>	
Character of Beds	Thickness (in Feet)
Sandstone of Bullhead Mountain formation.	200
Concealed (shale?).	20-30
Limestone, hard, grey, siliceous.	10
Shale, blue-black, marine, pure, in which are intercalated bands of limestone 8 inches to a foot thick separated uniformly by about 4 feet of shale.	65
Limestone, massive, hard, blue-grey on fracture, weathers dirty yellow, forms cliff.	20
Shale, black, hard, hackly in large proportion, marine.	40
Limestone, weathers into gnarled shapes, blue-grey on fracture.	3
Sandstone and limestone alternating, layers prominent, weathers into flat surface.	3
Shale of same composition as others, but breaking to angular fragments with more or less plane surfaces.	3
Limestone, very siliceous, hard, weathers into angular surface of yellow-grey colour; is steel-grey on fresh fracture.	5-6
Shale, black, hard, hackly.	2½
Limestone, with 6-inch median parting of shale; hard, steel-grey on fresh fracture, appears pure, weathers yellowish-grey.	5
Shale, blue-black, firm, pure, hackly in large proportion, contains very few fossils.	100

The upper part only of the formation is exposed, and an estimate of its thickness is impossible. It was planned to examine the upper valley of Moberly River in a search for more extensive exposures, but field-work was stopped by unusual weather before this could be begun. Information concerning the downward extent of this shale, therefore, and its relation to the Triassic limestone, is not available. McLearn² reports as concealed about 1,000 feet of strata between the uppermost Triassic and the lowermost Bullhead Mountain beds on Peace River, and it is probable that the Pine River formation is represented in that interval.

Prior to the writer's work the existence of the Pine River formation was unknown. Its age is not certain; three fossils, a species each of *Pinna*, *Pecten*, and *Lima*, indicate the possibility that the beds are Jurassic in age, according to Dr. T. W. Stanton and Dr. J. B. Reeside of the United States Geological Survey, but the evidence is not good enough to warrant a definite statement.

Bullhead Mountain Formation—The section west of Hudson Hope on Peace River discloses beneath the St. John shales a thick series of coarse sandstone and shale of continental origin which have been described by McLearn³ as the Bullhead Mountain formation. On Peace River the upper part of the formation consists of sandstone and shale, with several beds of high-grade coal, and the lower part consists of massive, coarse-grained, cross-bedded sandstone. The total thickness there is about 3,000 feet.

The formation is exposed on Pine River east of Crassier Creek, where the upturning of the series brings it high into the valley sides on the east flank of the Pine River anticline, and at the mouth of Commotion Creek, where the contact with the overlying St. John shale is approximately 300 feet above the level of Pine River on the crest of the Commotion Creek fold. At the latter locality the upper 200 feet of the formation are well exposed in the canyon of Commotion Creek.

²Op. cit., p. 26.

³McLearn, F. H.; Peace River Section, Geol. Surv. Can., Summ. Rept., 1917, Pt. C, p. 16.

The upper member of the Bullhead Mountain formation consists of about 130 feet of extremely hard, resistant conglomerate, the pebbles of which are almost uniformly $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter, and which consist of flint, chert, and quartz. They are very well sorted, and are firmly bound by a silica cement. A green chert, which appears to have been stained by glauconite, is prominent as a rule, and inasmuch as it does not exist in any of the clastic rocks above the Bullhead Mountain, it is interesting as a means of identification of the rock, as well as an index to changes in the continental mass to the west as a result of whose disintegration the Cretaceous clastic rocks were formed.

The conglomerate is characteristic in appearance, its distinct mineral content and habit making it lithologically the most easily recognized of any of the Cretaceous beds of the region. Pebbles and small boulders of it are found in all of the larger stream-beds of the area, and although it is clear in some places that they have been transported there by glacial agents, their widespread occurrence gives evidence of the great lateral extent of the formation.

Below the conglomerate is sandstone which decreases gradually in hardness for a vertical distance of 600 feet. Below this sandstone is another massive bed which was seen at a distance in the Upper Pine Valley; this may also be conglomerate. Below that bed less massive sandstone and possibly shale occupy the remaining 600 feet to the top of the Pine River formation. The entire thickness of the formation is contained in the hill east of Crassier Creek and north of Pine River, but none of it is exposed save the massive members mentioned, the remainder being covered by the soil and the dense sub-arctic vegetation.

St. John Formation.—The Bullhead Mountain beds are overlain by the St. John formation, which consists of 1,400 to 2,200 feet of blue-black to grey shale with intercalated sandstone members. On Peace River the formation is divisible into three members—an upper shale member 1,300 feet thick, a sandstone 80 feet thick, and a lower shale member 800 feet thick. The upper member consists of typical marine black shales, with little or no sandstone, but the lower member contains many

small thicknesses of sandstone. The Peace River section has been described by F. H. McLearn⁴.

The St. John shale is distributed in outcrop over the entire area. It forms the valley sides of Peace River in the vicinity of Hudson Hope. To the south, in the hills north of Moberly Lake, the overlying Dunvegan sandstone forms the surface, but in the valley of Moberly River the shale reappears. It outcrops in the valleys of Pine, Sukunka (above Marten Creek), and the Murray rivers; on Tuskoola and Table mountains; and in the area southwest of Gwillim Lake, the shale forming the lower valley sides as a rule, and the Dunvegan sandstone capping the ridges. In the area south of Peace River the lower part of the formation contains many irregular sandstone members, and the differentiation of the middle member of the Peace section is not clear.

All known exposures which reveal the contact between the St. John shales and the Dunvegan formation show a gradual transition from beds of distinctly marine origin to continental sandstone and shale with lignite and plant impressions. In Paquette Creek, on the north shore of Moberly Lake, the following section was measured at the top of the St. John formation:

Section on Paquette Creek

Formation	Character	Thickness (in feet)
Dunvegan.....	Sandstone, fine-grained at bottom, increasing in coarseness of grain to top.....	200
	Sandstone and shale, predominantly sandstone.....	22
	Shale and sandstone, predominantly shale.....	16
	Shale, black, sandy, with concretions of sandstone and ironstone.....	18
Transition Zone	Sandstone, massive, fine-grained, grey.....	1
	Shale as above.....	20
	Sandstone, platy, with shale intercalations.....	1
St. John.....	Shale, black, sandy in places, with limestone concretions and bits of comminuted plant remains.....	80
	Creek-bottom.	

A transition similar to this was noted wherever the contact

⁴McLearn, F. H.; Peace River Section, Geol. Surv. Can., Summ. Rept., 1917, Pt. C.

between the two formations was observed. The upper part of the formation is exposed in the vicinity of Moberly Lake, in the narrow valleys of the creeks tributary to the lake, and in the lower valley of Miller Creek. There it consists of marine shales, arenaceous as a rule, varying in character from fissile to hackly, and locally calcareous. On Pine River the upper shale is not commonly exposed, the hillsides being covered with vegetation, but such occurrences as were noted reveal at least 500 feet of shale containing no important sandstone members. In the area southeast of the Middle Fork the upper shale of the formation is entirely similar.

The lower part of the formation consists of a series of alternating shale and sandstone at all exposures seen by the writer. A typical section of this part of the formation is exposed in the valley of Commotion Creek above the falls, as follows:

Section Measured on Commotion Creek.

Formation	Character	Thickness (in feet)
St. John	Sandstone, massive, yellow-grey	70
	Shale, black, marine, thin-bedded, arenaceous, with even lines of ironstone concretions and thin bands of sandstone	550
	Sandstone, massive, medium-grained	25
	Sandstone, soft, friable, with carbonaceous matter ..	2
	Shale, black, sandy	3
	Lignite-seam	1
	Shale, sandy, with bands of carbonaceous matter approaching lignite in composition	35
	Sandstone, continental in origin, soft, friable, containing carbonaceous matter and leaf impressions ..	20
Bullhead Mountain	Conglomerates of Bullhead Mountain formation ..	130

On the northern escarpment of Tuskoola Mountain is exposed a series of shales and sandstones which have been assigned to the St. John and Dunvegan formations. The base of the Dunvegan beds is at an elevation of about 4500 feet on Tuskoola Mountain, and at the Middle Forks of Pine River its elevation is about 2000 feet. The identification of these beds

was made on the basis of marine fossils collected on Tuskoola Mountain, and if it is correct, either a fault or a sharp monoclinical fold exists in the intervening area, which must be examined before the identity of the beds in Tuskoola Mountain may be considered certain. Circumstances prevented such an examination during the course of this work. The presence of a fault is further suggested by the occurrence in Dickebusch Creek, a tributary of Sukunka River, of float bearing species of Kootenai plants common in the Bullhead Mountain formation. A fault large enough to account for the difference in elevation of the beds in question would bring the Bullhead Mountain beds to the surface east of Sukunka River.

Fossils collected in the vicinity of the mouth of Fish Creek on Murray River support the areal determination that the shale there is coeval with the Tuskoola Mountain shale. In the canyon of Gordon Creek there is no marine sandstone at the top of the St. John, the conglomerate and oyster-beds of the Tuskoola Mountain section being followed directly in downward succession by pure marine shale. The shale of Gordon Creek is traceable along the valleys of Murray River and Fish Creek to Gwillim Lake, and thence to the southeasternmost part of the area, on Flat Creek. The essential characteristics of the formation are constant over this area.

The thickness of the St. John formation is about 1,400 feet on Pine River. In the valley of Murray River between the crest of the Canyon anticline and the mouth of Wolverine River, where the only other nearly complete section of the formation is exposed, 1,500 feet were measured without reaching the base of the shale. There is thus a decrease in thickness from the Peace southward and westward; this is without doubt due to a westward replacement of the upper shale horizons by the continental beds of the Dunvegan formation.

Dunvegan Formation.—Directly overlying the marine shales of the St. John formation is a series of sandstones and continental shales named by Dawson the Dunvegan formation and studied recently by McLearn⁵. These beds, which for the most

⁵McLearn, F. H.: Peace River Section, Geol. Surv. Can., Summ. Rept., 1917, Pt. C, p. 18. Also McLearn, F. H.: Cretaceous, Lower Smoky River, Geol. Surv. Can., Summ. Rept., 1918, Pt. C.

part are moderately resistant to weathering agencies, form the main body of most of the hills in the areas. They extend in surface outcrop along the belt of moderate folding for the entire length of the region under consideration, and form the upper reaches of all the prominent hills save those at the edge of the disturbed belt, where the older formations have been brought up by the intense folding.

In the vicinity of Moberly Lake the lower beds of the Dunvegan formation form the upper reaches of the range of hills extending southeasterly from Hudson Hope to Pine River. These beds are more or less heterogeneous in composition and origin. At the contact with the underlying St. John formation there is a true gradation between marine shale and continental sandstone, the marine beds below passing conformably into brackish and fresh-water argillaceous sandstones, with fresh-water limestone in places. On the south shore of Moberly Lake two thin beds of lignite occur 45 and 65 feet above the base of the formation. Occasional lentils of hard limestone, as well as some sandy layers, contain a few fresh-water gastropods and pelecypods. These beds are succeeded above by subaerial sandstones, for the most part cross-grained, massive, and cross-bedded, containing leaf fragments whose disposition gives clear evidence of non-aqueous distribution of the materials.

This series of sandstones, with irregular lateral variation from continental to shore facies, extends in the higher elevations from Moberly Lake to the Middle Forks, where its base is approximately 150 feet above river-level, and a thickness of 600 feet, more or less, is irregularly exposed in the hill north of the fork. From this point south, in the valley of the Sukunka, the southwest dip carries the series under, and at Dickebusch Creek, where the base of the formation is estimated to be at least 1,000 feet beneath the surface, the facies changes from the sandstones typical of the Dunvegan as known to the north to a series of continental green shales, hardened calcareous muds, and grey, platy, cross-bedded, lenticular sandstones with flat nodules of black shale and occasional shaly layers. These beds are undoubtedly continental in origin. They contain seams of carbonaceous material and some low-grade coal.

The complete change in lithologic characteristics presented

by these beds affords reason for their consideration as a separate unit, and to meet the needs of his field terminology the writer called them the Sukunka beds. At present they may perhaps be included with the Dunvegan as an upper member of that formation, but future detailed work may reveal the necessity for their adoption as a separate formational unit. They may represent the westward phase of the Smoky River formation.

The thickness of the Sukunka beds is not known, their upper reaches not having been seen in detail by the writer, but their apparent continuation up Sukunka River from Dickebusch Creek to the synclinal axis beyond Marten Creek shows a thickness estimated at 1,000 feet or more. The valley sides here are well clothed with soil and grassy vegetation, and since the harder, cliff-making members of the series are the only ones which appear, a detailed examination of the beds was not possible.

The Sukunka beds appear also in the canyon of a small creek at the southwest corner of Gwillim Lake. Here they consist of massive sandstone layers 5 to 10 feet thick, granular grey-brown shales 2 to 4 feet thick, thin layers of micaceous grey sandstone breaking to feather-shaped fragments, hard, green-grey shales weathering brown, hackly to fissile, paper-thin black shales in thicknesses up to 2 feet, and thin-bedded sandstones. The beds at this locality are estimated to extend possibly 100 feet higher stratigraphically than the section examined in Dickebusch Creek.

At this locality, as well as in Dickebusch Creek, three species of fossil plants were found. These have been determined by Professor Edward W. Berry, of the Johns Hopkins University, as *Anemia fremonti* Knowlton, *Dryopteris coloradoensis* Knowlton, and *Populus* cf. *elegans* Lesquereux.

Of these the *Anemia* and *Dryopteris* are common in the Frontier formation of the western interior of the United States and the *Populus* is a typical Dakota species. The forms thus present to things which are of interest in the development of stratigraphic knowledge in the Canadian Northwest: (1), evidence additional to that afforded by invertebrate faunas from the Peace River area which points more clearly at each

new discovery to the Colorado age of the beds; and (2) further evidence of an interesting vertical persistence in northwestern North America of certain floras which to the south and elsewhere occur at earlier horizons, and representatives of which are found in Alaska in beds as young as Tertiary in age.

The Dunvegan proper—i. e., the series underlying the Sukunka beds—yielded the following plant species: *Protophyllum lecontianum* Lesquereux, *Platanus latior subintigrefolia* (Lesq.) Knowlton, *Menispermities reniformis* Dawson (?), *Aspidophyllum trilobatum* Lesquereux, *Cycadites unjiga* Dawson, *Platanus* sp., and *Taxodium* sp.

The general aspect of this assemblage is Dakota rather than Colorado, and its occurrence in the Dunvegan formation, which has been shown rather definitely to be Colorado in age, presents more evidence of the persistence of many Dakota forms. The *Menispermities* and the *Cycadites* are typical Dunvegan species, the former having been collected by the writer and others in previous work, and the latter having been found by Dawson in his exploration of the Peace River district in 1879. The *Aspidophyllum* is identical with the form described as *Protophyllum* by Dawson.

The Dunvegan formation thickens materially south of the Peace in the region between Hudson Hope and Moose Lake. If the whole series is found to be more or less coeval with the Dunvegan of Peace River, there was a basin in which deposition of sediments was much more rapid than to the north. However, further work may show parts of the thick series to belong to either the St. John or Smoky River periods, or both, and it is not improbable that the Sukunka beds may represent the westward extension of the deposits laid down in early Smoky River time.

GEOLOGY AS APPLIED TO OIL AND GAS

Possible Sources of Petroleum.—First-hand evidence of the presence of petroleum in the Cretaceous of the mountain front is rare. A few scattered seepages have been discovered, but on the whole the actual proof of petroleum in the rocks is not as good as might be desired. In the area here discussed the writer found no seepages or other certain evidence of petroleum.

The nearest known seepages occur about 45 miles east of

the eastern limit of the moderately folded belt, near the town of Rolla, B. C., on Pouce Coupe River. Oil has been found there seeping in small quantities from a sandstone which may be in the St. John formation, and gas-seeps are common in the vicinity. One oil-seep is known about 4 miles north of Peace River, on Moosé Creek.

Drilling has recently been started at the Rolla locality, solely on the evidence of the seepage, and early in December, 1921 the well was reported to be down 1900 feet, having encountered a flow of gas estimated at 10,000,000 feet, but no commercial production of petroleum. There is no appreciable fold there.

Seepages of petroleum have been reported variously to exist at many other places in northwest Canada, but thus far few have been actually found.

In the area here described three general parts of the stratigraphic column may be oil-bearing at depth. The Triassic limestone and sandstone may contain oil. The formation is not petroliferous at any known exposure, but all known exposures of it are in the disturbed belt, where metamorphism has taken place. It probably underlies the Pine River anticline at a depth of less than 1,000 feet, and since there is very little evidence of metamorphism there, it is worthy of a test. The Pine River formation, which includes at least 230 feet of black shale, may have been a source of petroleum, but it does not contain much promising reservoir rock. The sandstone in the lower part of the Bullhead Mountain formation would make a good reservoir and lenses of porous sandstone may be present in the Pine River shale east of its exposure, where it is beneath the surface.

The third hopeful part of the column is the lower part of the St. John shale. These beds promise more than any of the lower formations; in a vertical interval of 700 feet measured upward from the base of the formation, there are about 500 feet of black marine shale and 150 feet of interbedded sandstone. The sandstone beds are all porous, and would make good reservoir rock. The underlying conglomerate of the Bullhead Mountain formation is too firmly cemented to be considered as reservoir rock.

STRUCTURE

The geologic structure of the belt fronting the foot-hills of

Northwest Canada consists of a series of moderate undulations of the strata, the crests of the folds lying in the main parallel to the axis of the Rocky Mountain chain, and the continuity of many single structures being remarkable. The folds are nearly all open, and many of them are of dimensions and conformation ideal for the retention of any oil and gas which might have existed in the rocks they embrace beneath the surface.

The region between the western limit of the area and the mountains proper is known geologically as the Disturbed Belt. Within it the rocks have been folded and faulted to high degree, the forces which built up the Rocky Mountains having reacted on them with great intensity. To the east and southeast the effect of these huge forces was absorbed gradually until in the region which now forms the plains the strata underwent no change from their natural horizontal position. The belt considered in this report lies between these two extreme areas, and there, although the full strength of the forces had been partially dissipated, enough pressure due to the thrusting penetrated the local rocks to cause ordinarily unbroken flexures of comparatively gentle slope. The structures occur along two or three principal lines and the sharpness of the folding decreases regularly from west to east.

ANTICLINES THAT MAY CONTAIN OIL AND GAS

The major anticlines of the area are shown on the map. Brief remarks on each, taking them up in the order of their distance from Hudson Hope, follow:

Hudson Hope anticline.—The Hudson Hope anticline is a low fold of small extent, and is not by any means as promising a structure as others to the south. It is the most easily accessible fold in the area, however, and on that account has attracted the attention of oil men. Near the crest of the fold where it crosses Peace River the dips are about 2° on both flanks, and about a mile and a half west of the axis there is a structural terrace with a maximum west dip of about 15°. The axial extent of this fold is little known on account of lack of exposures. It is believed to be continuous with a faulted fold exposed in the west fork of Maurice Creek, but it probably dies out to the south.

At the crest of the fold the lower shale member of the St. John formation is exposed, and the strata beneath the surface consist of the remaining 600 to 700 feet of sandy shale and intercalated sandstone of the St. John formation, and the underlying continental sandstone, shale and coal of the Bullhead Mountain formation, at least 3000 feet thick, according to McLearn. The St. John beds, and possibly neighboring sandstones in the Bullhead Mountain formation, may yield oil, but the lower massive sandstone of the Bullhead Mountain offers little promise. The Hudson Hope anticline is hardly pronounced enough to have been thoroughly effective as a reservoir structure, and the comparatively small thickness of hopeful beds beneath it within ordinary drilling depth emphasizes the decision that it is not to be considered with the best anticlines of the region.

Moberly Lake anticline.—The Moberly Lake anticline is clearly visible in the hills south of Moberly Lake, where the massive lower sandstone of the Dunvegan formation stands out in sufficient boldness to display the arch very plainly. It is much better formed for the retention of petroleum than the Hudson Hope fold, having dips of 9° and 5° on its east and west flanks, respectively, and in the valley of Moberly River there are probably 1000 feet of St. John shale and sandstone beneath the surface at its crest. On the south side of the valley it is clearly defined, but to the northwest it appears to decrease in prominence. Southeast of its exposure at Moberly Lake the plateau is heavily covered with glacial drift as far as the middle forks of Pine River, and its presence there is known only indefinitely. It is inferred to exist continuously in this section because of west dips in the valley of Centurian Creek about 4 miles above its mouth—the strata must somewhere arch over to the east, into the broad syncline of the plains—and because of the strong possibility that the Table Mountain anticline, a broad, low structure that crosses the Pine River at Table Mountain, is continuous with it.

Miller Creek anticlines.—The Miller Creek anticlines are next in order of accessibility. The northernmost major fold crosses Miller Creek 4 miles from its mouth, and is about 30 miles by trail from Hudson Hope. On its east flank the dips

are moderate, ranging from 2° to 8°, but the west flank plunges sharply, having a maximum observed dip of 62°, and flexing upward again in an acute syncline whose axis is not farther than one-quarter mile from the crest of the fold. The St. John shales outcrop at the axis of this anticline, and the sandstones in the lower part of that formation are estimated to be about 1,000 feet below the surface on Miller Creek. This anticline is flanked by one to the south which is not so steeply folded, the dips of its flanks averaging about 8°. Beyond are several minor undulations which are not of sufficient prominence to warrant their consideration here.

The conformation of the first anticline is hardly ideal. The second structure is better formed than the first, and if the locality is to be tested it will merit the first attempt; however, it is apparently local in nature and the area of its flanks is small.

The Pine River anticline.—The Pine River anticline, as reference to the map will show, is a pronounced structure. On its east flank the dips attain a maximum of 25° in the hills east of Pass Creek, and decreases gradually in steepness to Peavine Flat, where the beds are horizontally disposed. On the west flank dips as high as 60° occur. The fold is thus distinctly asymmetric, the west flank being the steeper. Its degree of sharpness is certainly ample for the retention of petroleum, and the large areal extent of its flanks and their apparent freedom from excessive metamorphism place it among those structures which are to be classed as hopeful.

The beds beneath it are not definitely known; the lowest beds seen by the writer outcrop at its crest on Crassier Creek, and the nearest exposed section of the lower rocks, on Peace River, does not disclose^a the beds between the Schooler Creek

^aMcLearn, F. H., *Mesozoic of Upper Peace River*, B. C., Geol. Surv. Can. Summary Rept. 1920, Part B, p. 36.

and Bullhead Mountain formations. It is probable, however, that the uppermost known Triassic beds are within 1000 feet of the surface in the Pine River valley at Pass Creek, and it offers therefore the best site in the area for a test of the lower formations.

The Commotion Creek dome.—The Commotion Creek dome occurs along the same general line of folding as that found on

Miller Creek. Its outlines are exposed in the rude cross cut into the rocks by Pine River, Commotion Creek, and Goodrich Creek, and inspection of the outcrops presented there shows the fold to have a roughly elliptical form, the long axis extending in a direction a few degrees west of north, and the dips being steeper on the north side. The existence of the structure has undoubtedly determined the location of Commotion and Goodrich Creeks; hence its almost perfect quadrisection by the three drainage-channels.

The top of the Bullhead Mountain formation is about 300 feet above the level of Pine River at the apex of the fold, and the underlying section consists accordingly of approximately 1,200 feet of the sandstone, shale, and coal, of the Bullhead Mountain formation, with the Pine River shale and limestone below. The possibility of oil-bearing horizons below the Bullhead Mountain formation, coupled with the dome-like shape of the structure, presents a geologically attractive situation as far as oil and gas are concerned.

The Table Mountain anticline.—This fold may be the extension of the Moberly Lake anticline. Its crest appears to have the usual northwest and southeast direction, and it crosses Pine River near the eastern end of Table Mountain. It is not a pronounced structure; the dips on the east flank are at most 3°, and on the west flank the average dip is approximately the same, although on a structural terrace visible in the eastern end of the hill north of the Middle Forks west dips as high as 10° are measurable over a short distance.

In the Pine River Valley, where a drilling location would be most advisable in the interest of accessibility, depth of worthwhile drilling, and general economy of prospecting, the top of the St. John shales is at least 1,000 feet above river-level. The total thickness of the St. John shales is not known exactly in this locality, but it is not likely to be much different from the 1,400 feet measured on the Pine at Boulder Creek, and the thickness of hopeful strata below the surface is probably not more than 400 feet. Below that lies the 1,500 feet or more of the Bullhead Mountain formation, in the main body of which no oil need be expected. A prediction concerning the possibilities in beds below is not entirely safe; the Pine River shales may be

present at a depth of from 1,900 to 2,200 feet, but since nothing is known as to their lateral persistence to the east it is not possible to make a valuable estimate of the chances in deep drilling on the Table Mountain fold. A borehole on the Boulder Creek dome would yield information which might throw considerable light on this question, and, at all events, if it is desired to test the Pine River formation the Boulder Creek locality far excels any other in point of drilling depth, amount of hard rock to be penetrated, and degree of sureness of the presence of the formation underground.

Remaining folds in southern part of area.—The folds south of Pine River are at present so difficult of access that they will probably not be tested for many years, unless production is obtained at some more accessible locality in the area.

The structure in the Sukunka Valley is synclinal for about 10 miles above its mouth. The first major anticline observable occurs near the mouth of Brush Creek; it is mapped as the Sukunka anticline. Its relation to the other structures of the area is not entirely clear. Its crest probably follows the north-westerly trend of the belt, but this is by no means certain. Extreme irregularities of strike on its flanks make it impossible to define its contour without detailed work involving far more time than that available to the writer, and its inaccessibility discouraged giving it more attention than that possible in reconnaissance. It may form the rim of the wide synclinal basin south of Pine River, and as such may be continuous with the Boulder Creek-Miller Creek fold-line to the north and the Rocky Mountain Lake fold-line to the south.

The conformation of the Sukunka anticline is good, dips on the east flank ranging from 5° to 10° in the vicinity of the crest and on the west flank from 15° to 40° , and the strata beneath the surface on the Sukunka River consist of St. John shale and sandstone to a probable depth of 800 feet.

The longest apparently continuous fold in the area occurs between Rocky Mountain Lake and Flat Creek. Its presence has been observed by the writer at the forks of Flat Creek, 18 miles from Murray River; at the mouth of Flat Creek; on Bull-moose Creek near its mouth and 2 miles up-stream; at the west end of Moose Lake and at the west end of Rocky Mountain

Lake. Although nothing is known of its presence between these localities, their alignment indicates the strong possibility of its continuity. This long fold, which may be called the Flat Creek anticline, is flexed moderately at most of the points which have been observed, and is accordingly worthy of consideration as a possible container of petroleum.

At its exposures in the valleys of Flat Creek, Murray River, and Bullmoose Creek, the fold embraces beneath the surface a small thickness of the St. John shales and the full thickness of the Bullhead Mountain formation. It is likely that the top of the Bullhead Mountain formation is not far beneath the surface in the general vicinity of Murray River, and that accordingly the value of the structure in terms of present knowledge is questionable.

The most favorable localities, geologically considered, on this fold are those at the western ends of Rocky Mountain and Moose Lakes, where the underlying strata consist of nearly the entire thickness of the St. John shale.

About 6 miles below the mouth of Flat Creek a fold, called the Canyon anticline, crosses the valley of Murray River. In degree of flexure it is less pronounced than the Flat Creek fold, which succeeds it to the southwest, but it is clearly defined, the dips on the east flank being in the general neighborhood of 9° and on the west flank between 7° and 15° . It probably dies out to the northwest, and to the southwest its extension is not certain, although a fold which may be integral with it occurs in the valley of the East Fork of Flat Creek about 3 miles above the forks of the creek. Its contour on Murray River is favorable to the storing of oil, and inasmuch as the major portion of the St. John shales probably underlies the surface at its crest, it is worthy of note geologically, but it is at present too difficult of access to be considered on economic grounds.

A pronounced fold of almost symmetrical proportion occurs in the hills west of Bullmoose Creek in the vicinity of the trail from Moose Lake to Wolverine River. It is indicated on the map as the Bullmoose Creek anticline. Northwest and southeast of this locality the structure along the line of the fold is much broken up and really forms the outer edge of the Dis-

turbed Belt, but at the locality mentioned a somewhat hurried examination revealed no extreme contortion of the strata. At some point along the crest of the fold and in the general vicinity of the trail mentioned a test would be advisable in the existence of some sort of transportation facility, but the great cost of exploratory drilling at so great a distance from existing lines of freight-travel precludes active interest in the structure for some time to come. It is probable that at least half of the St. John formation underlies the surface at the apex of the fold.

Minor folds.—The flanks of the major structures mentioned above are, in some places where the dip is low, flexed slightly into minor folds of local extent. These smaller structures should not be considered as places for preliminary tests of the region, but inasmuch as certain of them include beneath the surface the most attractive formations of the series, they may be considered briefly.

Several minor undulations occur in the valley of Miller Creek. Their location and degree of flexure are indicated on the map. One north of the main Miller Creek folds includes the major part of the St. John shales beneath its crest, and those to the south include the entire thickness of these shales with part of the overlying Dunvegan formation.

Reversals of dip, indicating a small local "roll" in the structure, occur in 7-Mile Creek, in the Sukunka drainage area. This fold embraces in sub-surface formation the lower half of the Dunvegan formation and the underlying St. John shales, and consequently may merit attention if these formations are found to contain oil.

Another minor fold exists in the narrow valley of Fish Creek near its mouth. This is perhaps the most interesting of the minor folds observed; the section underlying it embodies the most promising part of the St. John shales, and the dips on its flanks near the crest range between 4° and 6°.

TRANSPORTATION

At present the region is accessible via three routes of travel, one from the west and two from the east. The western route, from Fort Gorge via the Giscome Portage, Crooked River, and Parsnip River to the Peace, is a water route, and is preferred

by some prospectors, travellers, and engineers for comparatively light travel. It is not a good route for the transportation of heavy equipment. The routes from the east leave the end of steel on the Edmonton, Dunvegan & British Columbia Railway at Peace River Crossing and Spirit River or Grande Prairie respectively. The first of these is the most used and is the best for the transportation of all classes of freight; it makes use of Peace River, which is navigable by vessels of light draught between Fort Vermillion and Hudson Hope. The season for navigation on the stretch between Peace River Crossing and Hudson Hope includes the months of June, July, and August as a rule, and in some years the large steamer makes the trip in September. Smaller craft ply the river as late as the first formation of ice.

The third route mentioned is a land route. From the railway points of Spirit River and Grande Prairie wagon-trails lead to Pouce Coupe, whence a more or less passable wagon-trail leads to Pine River at the mouth of the Murray, at the eastern edge of the area in question. The trail from Spirit River to Pouce Coupe is not used in summer on account of muskeg; it is a winter trail, and is used chiefly by the farmers of the Pouce Coupe Prairie for the haulage of their grain to the railroad. The road from Grande Prairie to Pouce Coupe is by far the better; it is passable to automobiles in dry weather and is extensively used for freighting into the Pouce Coupe district.

West of Pine River at the mouth of the Murray travel by wagon would involve much road-cutting. A road is supposed to exist as far as Hudson Hope, but it is not used by teams, and it is not likely that a wagon could make the trip without much road-building work.

Within the area travel is nearly all by pack-train in summer and by sleigh in winter. Wagon-roads exist about Hudson Hope and on Lone Prairie, but they are of local importance only, and most of them would not suffice in their present state for the haulage of heavy freight.

The transportation of equipment from the rail head to any of the localities at which drilling might be contemplated would involve the cutting and grading of road if the materials were to be hauled in summer. In winter the frozen rivers offer

roadways to sleighs when the ice is favorable, and the problem of present-day transportation of drilling materials to the region must not be considered without examining the possibilities of winter travel.

Suggestions for exploratory travel.—Travel for purposes of exploration in the Rocky Mountain front region must be by pack train, or, in areas accessible by water, by canoe. Pack travel is the most used, and the geologist who contemplates work in the belt anywhere north of Athabaska River should familiarize himself with the peculiar demands of northern travel. Some very good hints are given in a Handbook of Travel, published by the Harvard University Press.

The trails are not good, as a rule, and travel is necessarily slow. In the particular area described in this paper the main trails are better than elsewhere, and the geologist may travel expeditiously on them with horses. The side excursions necessary to geologic work are best made afoot. In the area adjoining on the southeast, between Flat Creek and Athabaska River, pack travel is much more difficult on account of muskeg and windfall, and the pack train should be in charge of an experienced man.

Experience has shown that the number of horses needed for a stay of five or six weeks in the wilderness, with a carefully selected outfit and stock of provisions, is about one and a half to the man, including saddle animals. It is advisable to take an extra animal. Horses may usually be hired or bought at the chief starting points of expedition, but no geologist should leave Edmonton or Peace River Crossing without first finding out whether animals are available in his territory. The animals can live comfortably on the luxuriant grasses that are almost everywhere plentiful during July, August, and September. It is impossible to carry feed expeditiously. A packer who knows the location of feeding grounds is worth many hours of valuable time to the party, for the camping places must be chosen with first regard for the needs of the horses. Men who have disregarded this prime consideration have come to grief. The geologist must make up his mind to adapt his work as well as possible on long trips to the routes and stopping places that will allow the horses to thrive.

The equipment should be as light as possible, and should be stripped down to those light things that are absolutely essential. As much dried food as possible should be taken. Tents should be of silk, beds, if possible, of eiderdown. Anything easily breakable will not last long in the average pack. Mosquito bars are absolutely essential; the writer has found a silk tent, with canvas floor and mosquito door, about as good as anything. Citronella preparations may help. Waterproof leather boots are good to have at times, and in wet years they save much discomfort.

It is advisable to have fibre pack boxes, specially built by dealers in sporting goods, for instruments, stationery and other such equipment, and everything that can not stand a wetting should be in waterproof covering. Everyone should always have with him a supply of matches in a waterproof box. Clothes for both cold and temperate weather should be taken. Packsacks, with tump-line and forehead straps, for making short trips with supplies on the back, and light bedding are very valuable in case it is necessary to go off for more than a day into country impenetrable by horses. The .22 calibre rifle is the most serviceable of all, except in the big game season, when a .30 U. S. Government '06 is best, and the .303 British or the .32 Winchester Special are good. A .22 pistol is a valuable arm, and carbines, not rifles, are best for pack travel.

A medical chest, containing common remedies and surgical equipment for ordinary accidents, should be included, and some one in the party should familiarize himself with the treatment of ordinary injuries and illness. It is well also to know something about the ordinary diseases of the horse.

A good handbook of medicine⁷ will furnish all of the information necessary to cover cases that can be treated away from hospitals. Very serious injury, such as a compound fracture of the thigh, is almost certain to result in death unless the patient can be removed to a hospital within a comparatively short time, and this fact should be uppermost in the mind of the geologist when he is tempted to risk physical injury in a remote place.

⁷See "Prevention of Disease and Care of the Sick", Miscellaneous Publication No. 17, U. S. Public Health Service.

Ration lists such as those used by Alaskan parties are the best to follow in buying provisions; they have been published in several handbooks on exploring.⁸

The suggestions given above are somewhat bare, and largely unexplained, but the geologist who starts out to work in the north will soon discover the reason for them. They are offered here as a possible help to any who may be called upon to undertake a new experience in travelling the northern wilderness.

⁸Paige, Sidney: *Hayes's Handbook for Field Geologists*, p. 15, New York, John Wiley and Sons, 1921.

DISCUSSION

ON DIAMOND DRILLING

In Volume 5, Number 6, page 674, of this Bulletin appeared a discussion by Mr. Charles E. Straub, on the article on Drilling Oil Wells with the Diamond Drill, by Frank A. Edson, which appeared in Volume 5, Number 5 of the Bulletin.

Mr. Straub, while pointing out the desirability of core drilling, cites several drawbacks which he considers will prevent the general use of the diamond drill in oil exploration. The writer has had considerable experience with diamond drilling, both in the various mining districts and in oil work, and believes that the diamond drill can be used to great advantage in certain phases of oil exploration. The objections to which Mr. Straub refers are not now so serious as they perhaps were at the time he made his investigation of core drilling and they present no real obstacle to the use of the diamond drill. During the past two or three years, the manufacturers of diamond drills have given considerable attention to the adaptation of the equipment to oil field work, and much progress has been made.

Diamond drills and equipment are now made to cut holes as large as 8 inches in diameter, and drills of this type, making large holes, are now in successful operation in the oil fields of Mexico. Moreover, these drills can be used to rotate fish-tail bits or other of similar type, used in ordinary rotary practice, and by the use of mud-laden fluid, as with a rotary, the diamond drill can be used to penetrate soft, caving formations, which, in older practice, would have been considered entirely unsuited for diamond drilling. Also by the use of the double tube, or floating tube core-barrel, the core is protected from the water action by an inner tube, and cores of small or large diameter even in soft or friable material such as shale, or loosely consolidated sandstone, are successfully taken.

These large diamond drills can also be used in combination with the cable tools outfits. The steam cylinders can be omitted from the diamond drill and the drill driven by sprocket chain connection with a pulley mounted on the band-wheel shaft of the standard rig. The drill can be quickly connected and used when drilling in hard formations, or where it is desired to secure cores. When such work is completed, it can be slid out of the way and churn drilling resumed.

The chief point which the writer wishes to make is that undue objection to diamond drilling has been made on account of the cost of the necessary carbon; the carbon loss in drilling; and the extra labor cost on account of the necessity for expert service in the person of the diamond-setter. Let us consider these points in order:

(1) *Cost of carbon.* The carbon required for the ordinary drilling operation will range in value from \$2500 for the smaller sizes of bits, up to \$5000 for the big bits referred to above. These figures contemplate enough stones to set two bits, though, as will be pointed out under (3),

this is not really necessary. But even taking \$5000 as a representative figure for the purpose, it is at once evident that this is not a large amount compared with the cost of some of the equipment that makes up the ordinary cable-tools or rotary outfit. And much more than this amount may be saved on a single test in a wild-cat region through the lower transportation charges and smaller investment in casing which is made possible through the use of the diamond drill. It should be remembered, also, that this investment is not an outlay to be charged to a single hole, but represents an accessory which can be used over and over in successive holes and still have a readily realized salvage value until the stones have worn to a size too small for efficient use.

(2) *Carbon wear or loss.* Were this as great in the oil fields as in many of the mining districts, it would mean a very serious objection to the use of the diamond drill in oil work. As a matter of fact, however, the actual carbon wear in the sedimentary formations of most of the oil fields is extremely small. On one contract in northern Oklahoma, 4000 feet of drilling in shales and limestones showed a carbon loss of only 8c per foot of drilling, and many thousand feet of drilling in similar formations in the Texas, Colorado, New Mexico, Illinois and Mexico show a loss of less than 10c a foot. Such results would not be secured in all cases, but they are sufficient to show that the carbon loss in sedimentary formations is not a serious cost factor.

(3) *Expert labor required to set the bits.* The work in northern Oklahoma, already referred to, shows that a single bit would run from 400 to 800 feet before the metal had been worn sufficiently to require resetting. It is evident, therefore, that resetting may be required only once or twice a month; that, should a company desire to limit its investment to a single bit, there would be no serious loss of time involved for resetting; and, that, while expert services are required when the bit must be set, the setter need not be retained for this purpose only but can be employed on other work in connection with the operating of the drills. On many of the one-drill jobs, the setter is not an extra man, but runs the drill on one tower and at the infrequent intervals, when resetting the bit is necessary, takes a few hours off (not more than three for the ordinary size of bit) for this purpose. If enough carbon is carried for two bits, he can set the extra bit on a Sunday, or in a short time when he is off tower. In larger or more difficult operations, where the services of a foreman would be required, regardless of what method of drilling is used, this man can set the bits when necessary without in any way interfering with his duties as foreman.

Summarizing the points made above: (1) Diamond drills are now made to drill holes of large diameter, and these drills can be used in combination with cable-tools outfits, or for the rotation of fish-tail bits of the rotary type. (2) "Washing" or wearing of cores is prevented by the use of the double tube core-barrel. (3) The investment in carbon is not large compared with the value of other drilling equipment, and is fre-

quently saved in full by lower transportation and casing costs made possible by diamond drilling. (4) Actual carbon wear in sedimentary formations of the oil districts is very small. (5) Bits will run several hundred feet without resetting. (6) The diamond setter is not an expensive and partially employed extra, but will also run the drill on one tower on a one-drill job, or will act as foreman where several drills are at work, or where a particularly difficult drilling operation warrants the services of a "tool pusher" for the given job.

Minneapolis, Minnesota.

P. W. DONOVAN.

Feb. 16, 1922.

GEOLOGICAL NOTES

PRELIMINARY REPORT ON UNDERGROUND CONDITIONS IN THE HAYNESVILLE OIL FIELD, LOUISIANA

On June 30, 1921, the Bureau of Mines made a preliminary type-written report on Haynesville, Louisiana, accompanied by a small map of the field and four cross sections, which was sent direct to the companies actually operating in that field. As only about a dozen copies of these reports were distributed, it is available to but few and therefore a few of the points mentioned are repeated here.

The first well was the Roxana Petroleum Corporation's Taylor No. 1 drilled to a depth of 2,902 feet, or a distance of 52 feet below the top of the pay sand. This well was drilled with a rotary and the sand was not tested by lowering the fluid level. A column of mud fluid with a specific gravity of 1.2, 2,850 feet in height, exerts a pressure at the base of 1,484 pounds to the square inch, whereas, the rock pressure at this depth does not probably exceed 500 pounds to the square inch. Smitherman, et al, who originally blocked the acreage on advice of J. Y. Snyder and gave part of it to the Roxana for certain tests, cleaned out the old hole during November, 1920, and found some oil which caused them to drill a new well on the location on the south. The discovery of the oil sand in the second well was accidental and was due to lowering the fluid in the well and creating a suction by pulling out a plug bit.

The cross-sections show the Nacatoch sand at a depth of about 2,100 feet and the producing Blossom sand at a depth of about 2,800 feet. The former contains water. Plotted maps of the well log of the discovery well at ElDorado and a well at Homer can be obtained free from the National Petroleum News, Houston, Texas. The structure, as shown in the sections, is a nose with a north and east dip.

A table is given which shows the safe depth at which casing can be used and the report recommends that 6 inch line pipe weighing 19.36 pounds per foot is not sufficiently heavy for the wells:

Size Inches	Weight Per ft. Lbs.	Collapsing Pressure Pounds Per Sq. In.	Equi. Water Press. Cu. Ft.	Safe depth to use with factor of safety of 2.; Feet.
4½	12.74	2900	6680	2340
6	19.36	2277	5246	2623
	23.50	3114	7175	3587
8	25.41	1397	3220	1610
	29.21	1849	4262	2132
10	32.51	863	1988	994

By W. W. SCOTT

INVESTIGATIONS ON PERMEABILITY AND ABSORPTION OF "SANDS" FOR OIL, WATER, AND GAS, WITH REFERENCE TO THEIR NORMAL AND POSSIBLE YIELD.*

Experiments have been started by the U. S. Geological Survey on the rate of flow of oil, water, and gas under physical conditions as nearly as possible like those that exist in nature. The effect of cementation, size and shape of pores and grains, percentage distribution of sizes of grains, total pore space, unconsolidated fine material in pores of samples, and such other physical properties as pressure, temperature and viscosity of oil, which cause variations in the flow of oil through "sands," are to be studied. Experiments are to be made on the effect of the above-mentioned factors on absorption and retention of oil and water by their "sands."

Experiments will be made on chunk samples of "sands" of different physical properties from productive beds at various horizons to ascertain the percentage of recovery of oil by such methods as vacuum, compressed air, water flooding, and steam. In conjunction with these experiments, microscopic examinations of small fragments of the oil "sands," as well as of thin sections of these "sands," are being made to determine shapes and sizes of grains and pores, the mode of occurrence, location, and nature of the cementing material in the pores, and the manner in which these characteristics vary at different positions on anticlines and other structural features.

A comparative study of "sands" of the different fields of the United States and an intensive study of the application of experimental results to "sands" of specific areas or pools will be made. It is hoped that these studies will not only aid in the development of a field after it is discovered, but lead to a much better understanding of the forces that operate in the accumulation and migration of oil.

The work has been somewhat retarded by difficulty in obtaining suitable samples for the experiments, especially from wells distributed over a single pool. Samples of oil "sands" taken at random are of value, but to obtain the best results series of chunk samples must be taken from a well, showing variations in the "sands" from the top of the cap rock to the bottom of the "sand." The best material is diamond-drilled cores, and recent activities indicating that more and more drilling with core-saving machines is in progress are looked upon as presaging a much more complete knowledge of oil "sand" conditions than has heretofore been obtained.

The first progress report on this work, *The Determination of Pore Space of Oil and Gas Sands*, by the writer, was published in the *Bulletin of the American Institute of Mining and Metallurgical Engineers* for April, 1920. This report gives the progress of the work up to the time of publication.

A. F. MELCHER.

Washington, D. C. Feb. 15, 1922.

*Published by permission of The Director, U. S. Geological Survey.

OIL AND GAS PROSPECTS IN GARFIELD COUNTY, MONTANA

Detailed examinations of the geology of parts of Garfield County, in east-central Montana, south of the Missouri and east of the Musselshell, have been made by C. F. Bowen, Frank Reeves, W. T. Thom, jr., and C. E. Dobbin, of the United States Geological Survey, and reconnaissance examinations of the remainder of the county have been made by A. J. Collier, W. T. Thom, jr., and C. E. Dobbin.

GEOLOGIC STRUCTURE

A broad, shallow structural trough, called by Reeves the Blood Creek syncline, crosses Garfield County from west to east, passing near Ross and a short distance south of Jordan and Van Norman. In the region north of this trough the beds rise with a gentle and even slope, but in the region south of it they rise more rapidly and irregularly toward the zone of uplift that includes the Cat Creek, Alice dome, and Porcupine areas. The principal structural feature of the county is therefore a wide shallow tilted slightly toward the east, whose southwest rim is turned up rather steeply and somewhat crumpled.

SEDIMENTARY ROCKS

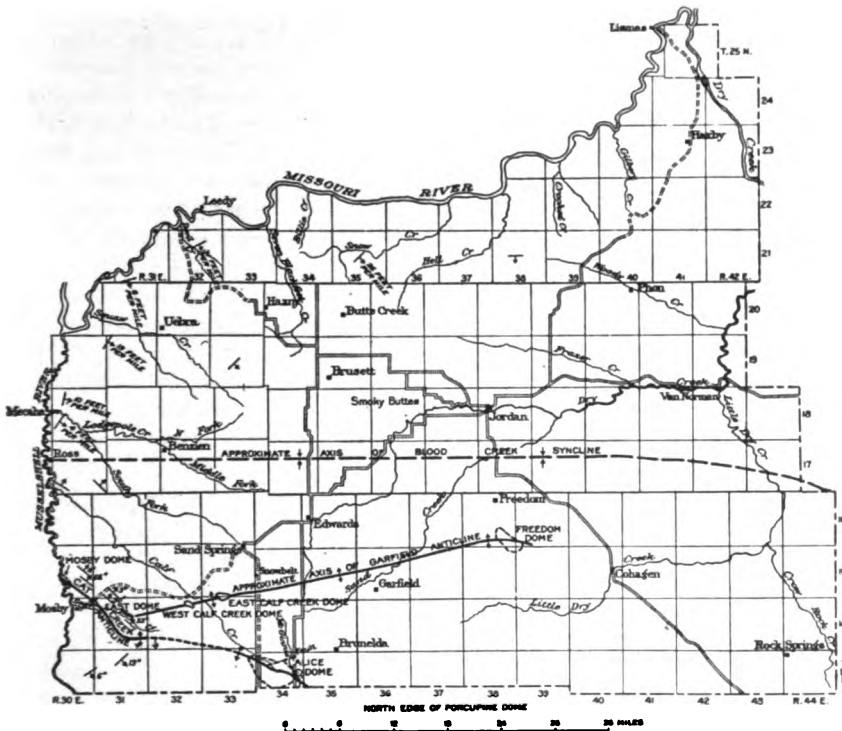
The rocks of possible interest to the oil producer that are exposed at the surface in Garfield County or that are believed to underlie it comprise about 8,000 feet of sedimentary strata, which belong to the formations described below. The formations are described below in order from the latest to the earliest.

The Fort Union formation, of early Eocene age, consists of beds of yellowish clay and sandstone of fresh-water origin and numerous persistent beds of lignite. The thickest remnants of the formation are found in the southeastern part of the county, where they probably attain a maximum thickness of about 450 feet.

The contacts between the upper Fort Union and the Lebo shale member, and between the Lebo and the underlying Lance, as mapped by Rogers¹, have not been traced over Garfield County. However, between the yellow strata of the high divides and the somber-hued badlands formed by the lower part of the Lance there is a zone that probably represents the Lebo shale, in which beds of thick rusty-red sandstone alternate with beds of dark shale containing lenses of crystals of glassy feldspar and pebbles of pumice. The base of this zone is placed tentatively at the bottom of the Big Dirty coal bed (Barker coal), which is mined near Sand Springs and which is conspicuously developed along the west side of the Musselshell-Dry divide and around Chalk Butte, near the head of Snow Creek. A similar dirty coal bed, probably the same bed, is exposed in the bluffs of Dry Creek just east of Van Norman. The thickness of the Lebo (?) member is variable but probably averages about 125 feet.

¹Rogers, G. S., The Little Sheep Mountain Coal Field, U. S. Geol. Survey, Bull. 531.

The Lance formation covers the surface of more than half of Garfield County. Its top is tentatively placed at the bottom of the Barker coal, so that it seems to be divisible into an upper and a lower member. The upper member, which consists of beds of soft yellow sandstone and sandy shale containing thin but persistent beds of lignite, shows a decided contrast in color to the darker beds above and below and has a thickness of about 150 feet. The lower member is about 550 feet thick and is com-



STRUCTURAL SKETCH MAP OF GARFIELD COUNTY, MONT.

Plate I.

posed principally of somber sandy shale but includes some massive irregular sandstone, especially near its top and its base. It is the surface formation of the Missouri "breaks" and of the lowlands of the Dry Creek valley, and it contains many bones of dinosaurs.

Below the Lance formation there is a conspicuous white sandstone that closely resembles the Fox Hills sandstone of the region south of Glendive, which is of Upper Cretaceous age and is the top formation of the Montana group. In Garfield County, as in the region near Glendive, the top of this white sandstone was considerably channeled before the sand that formed the brown sandstone which at many places overlies it, was laid

down upon it. Below this white sandstone is a transitional zone of thin marine sandstone and sandy shale, which merge gradually into the underlying normal Bearpaw shale. The thickness of these sandy beds tentatively referred to the Fox Hills ranges from 30 to 115 feet.

Beds of dark marine shale of the Bearpaw formation, of Upper Cretaceous age, which underlies the Fox Hills (?) sandstone, are exposed in a narrow belt along the northern and western borders of the county and along its southern line as far east as R. 39 E. They are exposed also along the axis of the Garfield anticline in the valleys of Calf and Sand creeks and on the crest of the Freedom dome. The thickness of the Bearpaw probably averages about 950 feet in Garfield County, although it seems to decrease somewhat toward the Porcupine dome and the Cat Creek uplift.

Sandstone and clay belonging to the Judith River formation are exposed along the northern margin of the Porcupine dome, on the southern line of the county between Rs. 35 and 39 E. inclusive, and form the crest of the Alice dome, in T. 13 N., R. 34 E. They also form the major rim or hogback that encircles the eastern end of the Cat Creek anticline. The formation is of fresh-water origin in the western part of the county, where it has a thickness of about 200 feet, but it grades into marine sandstone toward the east and grows thinner in that direction.

Beds of dark marine shale that include yellow and brown concretionary beds and that belong to the Claggett formation are exposed on the flanks of the Cat Creek anticline, where the formation has a thickness of 430 to 600 feet.

The basal formation of the Montana group, of the Upper Cretaceous series, is the Eagle formation, which outcrops in a zone of buff sandy shale about 75 feet thick near Mosby. Beneath the surface in the central and eastern parts of Garfield County this formation is probably represented by shale.

The upper members of the Colorado shale are exposed on the crest of the Cat Creek anticline and are the oldest rocks that come to the surface in Garfield County. At Cat Creek the formation is about 1,740 feet thick and consist principally of dark shale, but includes some concretionary beds. The thin sandy limestone that is known to drillers as the Mosby sand, and the Mowry shale member, lie 1,070 and 750 feet respectively above the Cat Creek sand, which has been selected by Reeves as the local base of the Colorado (in which it is included), and which is therefore in the general position of the Dakota sandstone.

At Cat Creek the Cat Creek sand is underlain by about 500 feet of red and variegated shale and coarse gray and yellow sandstone belonging to the Kootenai formation, of Lower Cretaceous age. At least some rocks representative of this formation probably underlie all of Garfield County.

According to Reeves, the Kootenai of the Cat Creek area is underlain by about 600 feet of probably Lower Cretaceous and Jurassic beds belonging to the Morrison and Ellis formations. These beds probably consist

of variegated shale in the upper half and of sandstone, shale, and limestone in the lower half and include some red shale at the base.

Reeves estimates that at Cat Creek this formation consists of 1,300 feet of gray, green, and black shale, black and gray limestone, and hard fine-grained sandstone. Fossils recently collected from the very top of the formation in the Big Snowy Mountains are believed to be of upper Mississippian age, though they may be lower Pennsylvanian.

The Madison limestone is of lower Mississippian age, and Reeves tentatively assigns to it a thickness of 2,100 feet at Cat Creek.

IGNEOUS ROCKS

The only rocks of igneous origin known to be exposed at the surface in Garfield County are those of Smoky Butte, a prominent landmark 10 miles west of Jordan. The igneous material occurs here as a large dike, which cuts strata as young as the basal part of the Fort Union formation.

HISTORY OF DEVELOPMENT

No wells have yet been drilled for oil or gas in Garfield County except on the Cat Creek fold. Prior to October, 1921, only three wells had been drilled, all in the area south of the axis of the Cat Creek fold. These obtained shows of oil in the Cat Creek or the Kootenai sands but made no commercial production. In October, 1921, Antelope No. 1 well, drilled by the Frantz Corporation in the northwest corner of sec. 26, T. 15 N., R. 30 E., was completed at a depth of 1,094 feet and is reported to have produced oil at the rate of about 100 barrels a day for some time after its completion.

The test well of the Montana Syndicate, in the southwest corner of sec. 15, T. 15 N., R. 30 E., was still being drilled at latest reports. The Mosby Oil Co. found water in the Cat Creek sand at 780 feet in the NW. $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 21, T. 15 N., R. 30 E., and the Mosby Dome Syndicate is reported to have obtained a good show of gas at 1,035 feet in their test well in sec. 34, T. 15 N., R. 30 E. Northern Pacific No. 1 well of the Frantz Corporation, drilled in the NE. $\frac{1}{4}$ Sw. $\frac{1}{4}$ sec. 27, T. 15 N., R. 30 E., obtained water in the upper sand and is reported to have been abandoned after having been drilled below 2,600 feet. The position of this well, which is south of the surface axis and structurally below the principal domes, is believed to have been unfavorable to the success of the test in view of the subsurface structural conditions which are thought to exist at Cat Creek.

The test well of the Absaroka Oil Development Co., the NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 1, T. 14 N., R. 30 E., obtained water in both the Cat Creek and the Lupton sands (the latter a sand in the Kootenai formation) and was abandoned.

PROSPECTS OF OBTAINING OIL IN GARFIELD COUNTY

Cat Creek anticline—As has been already stated, a small quantity of oil has already been obtained in Garfield County in the northwest corner

of sec. 26, T. 15 N., R. 30 E. From the map published by Lupton and Lee² it is apparent that this oil comes from the faulted belt north of the surface crest of the fold, and it is this general zone which is believed to be the more promising, especially the parts of it that lie north of the domes. It is also believed that the point of intersection of the axis of the Cat Creek fold with that of the Garfield fold, which should lie near or slightly northwest of the center of T. 14 N., R. 31 E., will probably be marked by a slight local dome, which possibly contains some oil. Experience in the Cat Creek field has shown that the crest of the fold in the Cat Creek sand lies several hundred feet north of the place where the crest appears at the surface, and the deeper beds will probably be offset still farther northward, to an extent proportionate to their greater depth. This interpretation is based on the belief that the steep north flank of the Cat Creek fold overlies a fault in the deeper rocks, and the similarity of the form of the Cat Creek fold to other pronounced folds in Montana suggests that, in testing the folds there that show steeper dips on one side than on the other, at least one test well should be located on the side of the steeper dip a short distance from the place where the crest appears at the surface.

The apparent presence of oil in the Madison limestone in the Soap Creek field and the occurrence of oil in the lower part of the Quadrant in the Devils Basin suggest that these horizons should be tested in the Cat Creek field. Apparently the most favorable location for a test well would be on the north side of the Mosby dome, in the valley of the Musselshell, where, according to estimates by Reeves, the top of the Madison should probably be reached about 3,200 feet below the surface. It may, however, be necessary to drill to a depth of 3,500 feet.

Alice dome.—The Alice dome lies on the zone of uplift that connects the Cat Creek fold with the Porcupine dome. It is estimated that the crest of the Alice dome lies somewhat north of the center of sec. 10, T. 13 N., R. 34 E., that the Cat Creek sand should probably be reached between 2,550 and 2,850 feet below the lowest rocks exposed on the crest of the dome; and that there is somewhat more than an even chance that a commercial pool of oil will be found beneath it.

Garfield anticline.—The Bearpaw shale has been exposed where Calf Creek crosses the axis of the Garfield anticline, and this shale area is usually referred to as the Calf Creek dome, but this area may perhaps be divided structurally into the East Calf Creek and West Calf Creek domes, whose approximate location is shown on the accompanying sketch map. The West Calf Creek dome may actually be devoid of closure, although it probably has a closure of a few feet, as compared with about 100 feet on the East Calf Creek dome. The axis of the Garfield anticline east of the East Calf Creek dome probably sags in secs. 34 or 35, T. 15 N., 33 E. East

²Lupton, C. T. and Lee, Wallace, Geology of the Cat Creek oil field, Montana: Am. Assoc. Petroleum Geologists Bull. vol. 5, No. 2, p. 256, 1921.

of this sag the beds rise about 175 feet in 5 miles, but it is not known whether the axis then continues approximately level or whether it undulates and produces additional domes. According to an unconfirmed rumor an uplift, usually referred to as the Jordan dome, lies on the axis of the Garfield anticline northeast of Garfield post office. The Freedom dome, which probably marks the east end of the Garfield anticline, is near the southeast corner of T. 16 N., R. 38 E. Observations made indicate that the northeast flank of this dome dips 18° to 20° , and maps courteously provided by the Absaroka Oil Development Co. show that the dome has a considerable closure. The Freedom dome is believed to be somewhat less promising than the Alice dome as a source of oil. The East Calf Creek dome and such other domes as may exist on the Garfield axis between Calf Creek and R. 37 E., are in turn believed to be less promising than the Freedom dome. It is therefore recommended that the Freedom dome be tested before drilling is undertaken elsewhere on the Garfield anticline. On all the domes mentioned it is estimated that the total thickness of the beds that lie between the top of the Bearpaw and the Cat Creek sand is about 3,800 feet, which is an approximate measure of the depth of projected test wells, as only a little of the Bearpaw has been eroded from these uplifts.

Remainder of the county.—West of Sand Springs, between the Garfield anticline and the Blood Creek syncline, there is an area in which the strata have been slightly flexed, producing domes that are so small and low that there is no likelihood of obtaining oil from them in commercial quantities. No structural uplifts favorable to the accumulation of oil are believed to lie north of the Blood Creek syncline, and the remainder of the county is not believed to contain favorable uplifts, other than those already mentioned, although only a hasty reconnaissance has been made of the extreme eastern and southeastern parts of the county.

POSSIBLE OIL SANDS

As has been pointed out, the Cat Creek sand and the sand of the Kootenai formation are the more probable sources of oil in Garfield County. The sand of the Ellis and the Quadrant formations and also the Madison limestone may possibly yield oil on the Cat Creek anticline, but elsewhere in the county they lie too far below the surface to be considered.

It is possible, though not probable, that the Eagle sandstone and Mosby sand may yield oil or gas in the county, and there is a slight possibility that marine sandstones of Judith River age may yield oil or gas in the domes along the Garfield anticline.

ACCESSIBILITY AND OPERATING CONDITIONS

Garfield County will be crossed by a proposed line of the Great Northern Railway, but it is remote from existing railroad lines. The northeastern part of the county is served by the towns of Uashua and Glasgow, on the Great Northern Railway, by means of a ferry at Lismas, and a

daily stage line connects Jordan with the Northern Pacific and the Chicago, Milwaukee & St. Paul railways at Miles City. A stage also runs three times a week between Sand Springs and the Chicago, Milwaukee & St. Paul Railway at Sumatra. The terminus of a branch of this railway at Winnett is about 20 miles west of Mosby and is the shipping point for concerns operating in the Cat Creek district. Except for this district the remainder of the southern and western parts of the county is most readily accessible by the roads which lead from Sumatra, Ingomar, and Miles City to Sand Springs, Edwards, and Jordan, respectively. The much-traveled "Green Trail," from Glendive to Lewistown, runs through Van Norman, Jordan, Edwards, Sand Springs, and Mosby. The accompanying sketch map shows the principal roads of the county and indicates which of them have been graded.

The drainage basin of Dry Creek above Van Norman has a gently rolling topography of moderate relief. The southern and southeastern parts of the county are somewhat rougher and have a maximum elevation of 600 or 700 feet above Dry Creek at Van Norman. The remainder of the marginal part of the county, in the lower valley of Dry Creek and along the Missouri and the Musselshell, is noted for its badland topography, of which the valley of Hell Creek is a well-known example. The maximum relief in this badland belt is about 1,000 feet, and the extreme dissection makes travel circuitous or difficult and renders numerous small areas inaccessible to vehicles.

Dry and Little Dry Creeks and their tributaries drain the greater part of Garfield County. A number of minor creeks, the largest of which are Hell Creek and Snow Creek, drain the northern badland area, and Squaw, Lodgepole, Calf, and Sage Hen creeks are the principal tributaries of the Musselshell that rise in western Garfield County. All these streams may cease to flow during dry periods late in summer, and their courses are then marked by small pools of standing water. The construction of dams, and the storage of water is therefore a warranted precaution before extensive drilling is undertaken, although artesian water will probably be found in the Judith River sandstones and also in the basal sandstones of the Lance in the central part of the county.

The numerous local lignite prospects would probably afford the cheapest fuel for drilling operations in Garfield County, though coal may be obtained from the railroad at Sumatra or Ingomar, or oil might be brought from Cat Creek, in spite of steep hills east of the Musselshell, which make heavy hauling from Mosby both difficult and costly.

W. T. THOM, JR., AND C. E. DOBBIN.

AGE OF THE BARNETT (LOWER BEND) SHALE OF CENTRAL TEXAS

Between the well known Marble Falls limestone which is so important as an oil producer in the north Texas fields, and the underlying Ellenburger (Ordovician) limestone there is present in most places a soft,

yellowish gray to black, clayey, bituminous shale. This shale was first differentiated from the associated strata by Udden¹ who described its occurrence at the outcrop in eastern San Saba County and included it under the name "Lower Bend shale" with the Bend series. Udden referred the Bend series to the Pennsylvanian. In a recent paper by Plummer and Moore² the Lower Bend shale has been given the name Barnett shale from a locality a few miles east of the town of San Saba in the Central Mineral Region where the shale is well exposed. Descriptions of lithologic character, measurements of outcrops, observations of stratigraphic relations and discussion of the contained fossils and their correlation are presented in this paper. Following the conclusions of the present writer reported in a paper read before the Association in 1919³, the Barnett shale is tentatively referred to the Pennsylvanian, in the contribution by Plummer and Moore though on account of conclusions by Girty⁴ that the lower Bend shale is really Mississippian, the division is placed under the heading "Beds of Uncertain Age."

The chief reasons for the correlation of the Barnett shale with the Pennsylvanian which has previously been proposed may be reviewed briefly. (1) The stratigraphic relations of the Barnett shale appear to indicate a close association with the overlying Marble Falls, limestone which is unquestionably lower Pennsylvanian. The Barnett shale rests with profound unconformity on the eroded surface of the Ordovician limestone but no evidence of an erosion break between the Barnett and Marble Falls was observed in the field. It may be concluded that the sequence of muddy clastic sediments represented by the Barnett shale and included limestone in the upper part and the overlying Marble Falls limestone, are the normal expectable sequence of deposits in a sea gradually advancing on the Llanorian old-land. Mississippian deposits, excluding from consideration the Barnett shale, are unknown in this region, either at the outcrop or from well records to the north. It may be regarded as rather unlikely, *a priori*, that the sea in which the Barnett was deposited marks a separate advance of the sea from that which left its record in the Marble Falls limestone. The stratigraphic relations of the shale and the physical history of the region appear to unite more or less closely the Barnett shale and the Marble Falls limestone. (2) Paleontologic evidence suggests a relationship between the Barnett shale and some of the formations, such as the Caney and Moorefield shales, which have been classified as upper Mississippian, but it has not seemed certain that the fossils

¹Udden, J. A., et al., Review of the geology of Texas, Bur Econ. Geol. and Tech., Texas, Bull. 44, p. 42, 1916.

²Plummer, F. B., and Moore, R. C., Stratigraphy of the Pennsylvanian formations of north-central Texas, Univ. of Texas, Bull. 2132, p. 23, 1921.

³Moore, R. C., The Bend series of central Texas, Bull. Am. Assn. Petr. Geol., vol 3, p. 218-19, 1919.

⁴Girty, G. H., The Bend formation and its correlation, Bull. Am. Assn. Petr. Geol., vol. 3, pp. 71-81, 1919.

from the Barnett shale were really identical with those from Mississippian beds elsewhere. Consideration of the faunal evidence is presented in some detail in the paper by Plummer and Moore⁵ which has been mentioned. It may be noted here that the somewhat doubtful record of *Fusulina*⁶ in the Barnett shale and the nature of other fossils are indicative of or are not inharmonious at least with the correlation of the Barnett with the Pennsylvanian, and that some fossils such as the coral *Paleacis*, in the Marble Falls, which occurs high in this formation, are elsewhere indicative of the Mississippian. There are a number of elements in the fauna of the Bend as a whole that are evidently derivative from the Mississippian and are more or less strongly suggestive of it. In short, it has been believed that the faunal evidence is in keeping with the conclusion that the Barnett shale marks the initial deposit of an advancing sea of early Pennsylvanian time in this region.

Studies of the cuttings from wells which were drilled through the Bend at three points north of the outcrop in San Saba and adjoining counties in central Texas have convinced Goldman⁷ that there is a break, marked by a zone of glauconite and phosphatic pebbles, between the Marble Falls and the black Barnett shale. It may be recorded here that following the 1921 meeting of the American Association of Petroleum Geologists at which the conclusions of Goldman were presented and discussed, arrangements were made by the U. S. Geological Survey for examination of the outcrops of the Barnett shale in San Saba County. A party consisting of Messrs. Goldman, Sellards, M. G. Cheney and the writer visited exposures of the Barnett-Marble Falls contact southeast and south of the town of San Saba and made careful observations of the beds in question with special reference to the occurrence of glauconite and phosphate pebbles and the distribution of fossils. Among the localities visited was that described by Moore⁸ on upper Cherokee Creek southwest of the town of Bend where the occurrence of abundant Barnett fossils had been reported in limestone which there was thought to represent the base at the Marble Falls formation.

It was found in all of the localities examined that there is more or less glauconite and phosphatic material at the top of the shale or at a horizon which may be regarded as marking the contact between the Barnett and Marble Falls and that the fossils peculiarly characteristic of the Barnett division do not range above this thin glauconitic and phosphatic zone. In the exposure on Cherokee creek the top of the Barnett division, thus defined, is a hard, drab extremely fossiliferous limestone not different

⁵Plummer, F. B., and Moore, R. C., loc. cit., pp. 26-32.

⁶A single specimen which is apparently referable without question to *Fusulina* was contained in a collection of fossils made by Mr. Plummer from marly beds in the Barnett shale near Barnett Springs, east of San

⁷Goldman, Marcus I., U. S. Geol. Survey, Prof. Paper 125, 1920.

⁸Moore, R. C., loc. cit., p. 224.

lithologically from many parts of the Marble Falls, but this bed of fossiliferous limestone is separated from the succeeding massive limestones by a thin parting, 1 to 3 inches thick, composed of clayey, glauconitic and phosphatic material. The fossils from the limestone below the thin break were not found above this layer and brachiopods found in the basal part of the Marble Falls limestone at this point were not found in the very fossiliferous limestone below the glauconite zone. The same essential conditions were found at the excellent exposure of the lower Bend rocks about two miles southeast of San Saba on the San Saba-Chapel road.

This evidence indicates that there is in fact a line of demarcation between the Barnett and the Marble Falls which is indicated by a zone of glauconite and phosphatic pebbles, and this line separates two distinct faunas. There is no question but that the fauna of the Barnett as thus defined is more closely related in its aspect to the Mississippian than the Pennsylvanian and that it is not continuous with the Marble Falls. As indicated in a more recently published summary of the north central Texas Pennsylvanian⁹ the Barnett may accordingly be referred tentatively to the Mississippian in accordance with Girty's earlier correlation. However it may be recalled that in formations such as parts of the Morrow and the Wapanucka, in Arkansas and Oklahoma there are fossils which are even more suggestive of Mississippian age than any found in the Barnett, yet these formations are commonly regarded as early Pennsylvanian. While it is significant that a definite line of division between successive faunas in the lower part of the Bend coincides with the glauconitic and phosphatic zone described by Goldman it may be recalled that there are a number of such glauconitic and phosphatic zones in the Bend.

The writing of this statement concerning the Barnett shale has been considerably delayed but it is believed that those who are engaged in the study of north Texas geology should be advised of the observations made at the outcrops of the Bend. In conclusion, it may be noted that, notwithstanding the demarcation of the Barnett from the succeeding formations which is now indicated, and the tentative reference of the shale to the upper Mississippian rather than the lower Pennsylvanian, the writer believes that there are a number of reasons, as stated in the early part of this discussion, for continuing to regard as unsettled the final correlation of the Barnett.

RAYMOND C. MOORE.

THE OIL AND GAS FIELDS OF ILLINOIS

The locations of the oil and gas fields, pipe lines, refineries, and anticlinal axes in Illinois are shown on a map printed in three colors, on a scale of 8 miles to the inch, just published by the United States Geological

⁹Moore, Raymond C. and Plummer, F. B., Jour. Geol., vol. XXX, p. 28, 1922.

Survey. These features are superimposed on a base map that shows counties, cities, railroads, and drainage, but the features of the oil and gas fields are made prominent by printing the base in gray, which though legible, does not interfere with the other data.

In the preparation of the map the best information available to the Geological Survey was utilized, and the map was subsequently improved by incorporating in it revisions and additions made by the Illinois Geological Survey as well as by geologists and officials of oil, gas, and pipe-line companies operating in the State.

This map, which should be of value to producers, refiners, and others who are interested in the oil and gas fields of Illinois, is sold for 50 cents a copy by the Director of the United States Geological Survey, Washington, D. C.

SOUTHERN MEXICO

Mr. Fred B. Ely reports that work in the states of Colima and Oaxaca, Mexico, is very interesting, but not very profitable from an oil production standpoint. The general type of fault block structure which is so characteristic of the Sierra Madre Mountains holds good for all of the coastal country as far south as Michoacan. There is no real coastal plain or folded sedimentary strata such as are ordinarily associated with oil deposits. Some individuals in this region are, however, sufficiently eager in the search for oil that they are preparing to drill on a volcanic plateau. "Chapapote," or at least material called that, is shown in beds of volcanic ash. South of Lake Chapala, Jalisco, is an interesting deposit of asphaltic material in Quaternary clays and shales in a volcanic basin. Similar deposits of asphalt have been reported in the southern part of Chiapas, though none are known to be of commercial importance.

REVIEWS AND NEW PUBLICATIONS

FULLER'S EARTH DEPOSIT AT OLMSTEAD, ILL.

BY CULLEN W. PARMELEE

Chemical and Metallurgical Engineering, Jan. 25, 1922, p. 177

About 1912 J. H. Gardner of the Kentucky Geological Survey noted some peculiar deposits in the Ohio River bluffs near Olmstead, Illinois, and sent samples of the material to C. C. Ruprecht, who had had considerable experience with fuller's earth. The latter tested these and other samples, optioned some land, and with associates erected a mill which has operated for more than a year. Recently the Sinclair Refining Company of Chicago has taken over this mill with 55 acres of adjoining land, and last summer the Standard Oil Company of Indiana purchased 155 acres near Olmstead, Illinois. Fuller's earth, a variety of clay formerly imported from England, is now produced in Florida, Georgia, Texas, Alabama, Nevada, Arkansas, California, Massachusetts, and Illinois. In 1920 a domestic production of 128,487 tons was valued at \$2,506,189, and imports reached \$221,893. Its principal use is to bleach mineral, animal, and vegetable oils.

The deposit at Caledonia, Illinois, near Olmstead, is in the Midway formation of the Tertiary, and occurs in a bluff over 100 feet high which extends along the river bank for about two miles. The section consists of about 10 feet of loose overburden underlain by 34 feet of high-grade fuller's earth. Below this is an additional 30 feet of the material rated as 80 per cent efficient. The material is shot, loaded on to wheelbarrows, and taken to the mill where it is crushed, heated in a rotary oil-bearing dryer to about 900°F. and the moisture is thus reduced to 3 to 5 per cent. Further crushing and screening produces three grades 16-20 and 30-60 mesh, for bleaching and filtration of mineral oil, and 60-300 mesh for filtering lard, vegetable oils, soap stock, etc. The sacked material is hygroscopic and increases its moisture content to 12 per cent during shipment. A production of 350 tons per month is reported with reserves estimated at four million tons.

Since this article was prepared but prior to going to press, the mill at Olmstead was destroyed by fire, and plans for rebuilding same have not been announced, but because of the importance of the deposit and its central location, an early resumption of activity is to be expected.

JAMES H. HANCE.

THE MONROE GAS FIELD, LOUISIANA

BY H. W. BELL AND R. A. CATTELL

Bulletin 9 of the Department of Conservation of the State of Louisiana has been compiled in co-operation with the United States Bureau of Mines, by H. W. Bell and R. A. Cattell, Petroleum Engineers and is distributed by the Department of Conservation, New Orleans, for 50c a copy.

This publication is the best yet submitted by the Department of Conservation and it is hoped that more work along this line will be authorized by the state. This matter is especially interesting at this time, due to the fact that Governor Parker is contemplating establishing a Geological Survey of Louisiana to carry on systematic work relative to the oil and gas industry of that state. Louisiana is one of the few large oil and gas producing states which has no official survey of any description, and as a result great economic loss has ensued by reason of the fact that oil and gas wells have been drilled haphazardly without proper supervision. Due to the soft formations and unconsolidated sands found in the oil producing areas of Louisiana, it is extremely important that some sort of co-operative measure, worked out preferably along the lines of the California State Mining Bureau, will be authorized by the state legislature.

Bulletin 9 outlines the fact that the Monroe gas field is probably one of the greatest potential gas fields yet discovered and has a proven productive area of over two hundred square miles. It is pointed out that the field should supply an amount of gas equal to a production of 150,000,000 cubic feet per day for 43 years. This statement may or may not be exaggerated, as the ultimate production of the gas will depend entirely upon proper operating methods. The chapter devoted to Geologic Features is very incomplete, but as the Bulletin is primarily one of a technical nature, this fact was very likely not stressed purposely.

The authors call attention to the Red River-Alabama Landing fault, as mapped by Veatch, in connection with the structural conditions of the field, but this phase has evidently not been given much attention, as detailed work in the field will reveal the fact that this much discussed fault, in this particular area, trends in a northeast-southwest direction, from in the vicinity of Alabama Landing, on the Ouchita River, to sec. 33, T. 23 N., R. 7 E., Morehouse Parish; and is a fault of very small magnitude and quite recent age, perhaps dating back not longer than the time of the New Madrid earthquake. Vertical displacement in the soft bed of Ouchita River and the physiographic features of the area contiguous to Bayou Bartholomew, as well as the well drilled by the Bell Oil & Gas Company, in sec. 13, T. 22 N., R. 6 E. all tend to prove this statement.

The fault lying along the southeastern flank of the field called the Monroe Fault by the authors, was mapped in February, 1920, but they evidently overlooked this fact and did not know of it until after the Florsheim and Breece wells were drilled in. This is the major fault of the area and extends from in the vicinity of Sicard, northeast to sec. 33, T. 23 N., R. 7 E. In discussing the subsurface geology, no mention has been made of the deep tests in the Monroe Gas Field nor have the red shales, which have been encountered by these wells, been mentioned. They are probably of Lower Cretaceous age.

Some very good data is given in that part of the Bulletin devoted to the gas reservoir and probable life of the field and the quality of the gas is discussed. Mention has been made of the gasoline content, which shows

a very marked decrease westward from the Monroe fault, and tends to prove the statement that the gas has migrated, and is migrating, vertically up this fault and from a deeper reservoir at least in the Lower Cretaceous, and accumulating in the structural "high" west of said fault.

A very authentic history of development is covered and the condition of the field at present is outlined. This section of the Bulletin contains some very important data, from an economic standpoint, as it shows conclusively the enormous waste which has occurred and which is at present going on in the Monroe gas field, and which can be remedied only by proper supervision and applied engineering methods.

The authors have given some very good rules to be followed in the drilling in of wells and the exclusion of water in this district. Figures on the production and consumption of gas in the Monroe field are given and a great many statistics relative to the gas consumption and rate charged for natural and artificial gas in the large cities within pipe line reach of this field are tabulated.

That part of the Bulletin devoted to the possibilities of expansion in the domestic and industrial utilization of this natural resource is all very feasible and too great stress can not be laid upon this by the people of Louisiana.

The carbon black industry is covered in a general way, but greater detail should be given to the listing of carbon black plants, their capacities, and the gasoline absorption plants connected with them. The losses in the manufacture of carbon black are stressed and this is one of the main things in which the state of Louisiana should be interested if they are to conserve their natural resources.

The authors have concluded their Bulletin by making a number of recommendations, all of which should receive the approval of every one interested in the economic production of oil and gas in that section of the country, and it is to be hoped that the state legislature will provide for proper relief along these lines. Taken as a whole Bulletin 9 is a very valuable contribution by the State of Louisiana, even though many phases of the geology of the area are omitted.

Tulsa, Oklahoma

J. WALLACE BOSTICK.

Feb. 14, 1922.

THE ECONOMIC ASPECTS OF GEOLOGY

By C. K. LEITH

Henry Holt and Company, New York, 1921

457 pages, 13 figures and diagrams

This book is a comprehensive digest of economic geology by one of its most able exponents who brings to his readers not only the critical comments of one of our foremost teachers and practitioners but of one who served as mineral adviser to the U. S. Shipping Board and in other governmental capacities during the Great War, and who thus had opportu-

ity to study in intimate detail the present international aspects of the mineral industry. It is not a text book in the ordinary sense of the term, but it should prove to be a real addition to the desk or library of anyone who is interested in world problems today.

A list of the chapter topics may serve to indicate the extent of the field surveyed. Chapter I, The economic applications of the several branches of geology; Chapter II, The common elements, minerals and rocks of the earth and their origins; Chapter III, Salient features of the geology and classification of mineral deposits; Chapter IV, Some general considerations of mineral resources; Chapter V, Water as a mineral resource; Chapter VI, The common rocks and soils as mineral resources; Chapter VII, The fertilizer group of minerals; Chapter VIII, The energy resources, coal, oil, gas, and asphalt; Chapter IX, Minerals used in the production of iron and steel (the ferro-alloy group); Chapter X, Copper, lead and zinc minerals; Chapter XI, Gold silver and platinum minerals; Chapter XII, Miscellaneous metallic minerals (ores of aluminum, antimony, arsenic, bismuth, cadmium, cobalt, mercury, tin, uranium and vanadium), Chapter XIII, Miscellaneous non-metallic minerals (abrasives, asbestos, barite, borax, bromine, fuller's earth, graphite, gypsum, mica, monazite, precious stones, salt, talc and soapstone); Chapter XIV, Exploration and development; Chapter XV, Valuation and taxation of mineral resources; Chapter XVI, Laws relating to mineral resources, Chapter XVII, Conservation of mineral resources; Chapter XVIII, International aspects of mineral resources; Chapter XIX, Geology and war; Chapter XX, Geology and engineering construction; Chapter XXI, Training, opportunities and ethics of the economic geologist.

In the discussion of these various topics the author exhibits a refreshing breadth of view combined with terse treatment. Technical descriptions are minimized and the book although of moderate length, has an unusually broad scope. To the student of geology, and of economic geology in particular, this presentation and brief analysis of the broader aspects and international phases of our mineral supplies will prove a most interesting and profitable study. For the business man of the world who would appreciate some of our larger problems which press for solution the book contains a wealth of information and suggestions. Students of human geography will find that the book sheds much light on many of their more important studies. Throughout the book there are numerous references to some of the larger unsolved problems in this field, accompanied with pertinent suggestions as to promising lines of research and attack.

Chapters XIV to XVIII contain much informational and suggestive comment on important and intimately related phases of the subject. The author's perspective and appreciation of the field are well shown in his brief statements of some of the opportunities and responsibilities which confront the economic geologist of today and tomorrow.

Chapter XIX on geology and war brings out some of the many ways in

which this earth science is of critical importance in time of war. Although we hope that armed conflicts may be remote future contingencies, the experiences in the recent war should bring home the value of geology as a weapon of high effectiveness.

Chapter XX on geology and engineering construction summarizes a few of the many applications in this field where the industrial world is availing itself more and more of the applications of earth studies.

Chapter XXI on the training, opportunities and ethics of the economic geologist is a fitting chapter with which to close such a volume. Broad training is necessary for breadth of view, and many of the problems now awaiting solution challenge the most careful consideration of the best trained minds. The field is the earth, and the opportunities are limited only by the individual.

A few quotations may serve to illustrate the character of the treatment accorded the subjects, and the admirable way in which the author presents his views.

"There is no phase of geology which at some time or place does not have its economic application."

"The remarkable concentration of the world's mining and smelting around the North Atlantic Basin * * * does not mean that nature has concentrated the mineral deposits here to this extent. It is an expression rather of the localized application of energy to mineral resources by the people of this part of the world. The application of the same amount of energy in other parts of the world would essentially change the distribution of current mineral production. The controlling factor is not the amount of minerals present in the ground; this is known to be large in other parts of the world and more will be found when necessary. Controlling factors must be looked for in historical, ethnological, and environmental conditions."

"Every country in the globe is deficient in supplies of some minerals. The United States is better off than any other country, but still lacks many mineral commodities. No single continent has sufficient reserves of all mineral commodities."

"Looking forward to the future, the problem of mineral reserves in general is not one of the possible ultimate amount which the earth may contain—presumably in no case is this deficient—but of the success with which the resource may be found and developed to keep up with the rapid acceleration of demand."

"At many times in the history of the mineral industry the end has apparently been in sight for certain products; but with the increased demand for these products has come increased activity in exploration, with the result that as yet no definite end has been approached for any one of them. The more immediate problems of the petroleum industry seem to the writer to be of rather different nature: first, whether the discovery and winning of the oil can be made to keep pace with the enormous acceleration of demand; and second, the adjustment of political and financial control of oil resources, the possession of which is becoming so increasingly vital to national prosperity."

"Exploration is passing from the highly hazardous stage of individual effort into a systematic business with calculable returns."

"Conservation of mineral resources may be defined as an effort to

strike a proper balance between the present and the future in the use of mineral raw materials."

"Most of the mineral resources have been concentrated by nature in a comparatively few places in the world; and when the two elements of conservation are considered—the materials themselves and the human energy expended in obtaining and using them—it is clear that any measure which interferes with the natural distribution of the favored ores is anti-conservational from the world standpoint."

"The main problem now is not one of total supplies, but of their effective and equitable distribution."

"In short, man is the multiplier and the mineral substance is the multiplicand in the product known as value."

Some of our students in petroleum engineering would probably modify Dr. Leith's statement that "About 50% of the oil in the porous strata of oil pools is ordinarily not recovered because it clings to the rock." As a result of detailed studies covering all of our American oil fields and with an unusually large amount of data available some of our investigators in the U. S. Bureau of Mines suggest that the total oil left in the rocks as unrecoverable under present methods of extraction is about 80% of the original content.

In the chapter on Valuation of Mineral Resources the author states that "In actual practice interest rates used in making valuations vary from 6 to 15 or 20%." J. R. Finlay in his recent book on Cost of Mining extends the upper limit to 50% or even more, and although most valuation work may come within the figures given by Dr. Leith, enough problems with greater hazards do come up to justify keeping the larger figures in mind.

A few more diagrams and illustrations might add to the value of the book without perceptible increase in its bulk. The material is so thoroughly boiled down and condensed that many readers might welcome a little additional assistance in visualizing the pen pictures which the author sketches all through the text.

Economic Aspects of Geology marks an important stage in the application of geology to civilization, and with Spurr's recent book entitled Political and Commercial Geology are two volumes which the reviewer cordially commends to the attention of all who would be thoughtful students of world affairs today.

JAS. H. HANCE.

HAYNESVILLE FIELD, LA.

The Department of Conservation of the State of Louisiana has published Bulletin 11 entitled: "The Haynesville Oil Field, Claiborne Parish, La.," by W. W. Scott of the U. S. Bureau of Mines, and B. K. Stroud, of the Department of Conservation. The Bulletin consists of 26 pages, a large structure contour map of the field and a cross-section through the field. It is distributed free from the Shreveport Office of the Department. Since publication the field has been extended one and one-half miles west and northwest.

HUNTON LIMESTONE PRODUCTION IN OKLAHOMA

Oklahoma Geological Survey Circular No. 10, published in March, entitled: "A Siluro-Devonian oil horizon in Southern Oklahoma," by Geo. D. Morgan, and distributed free, describes the producing horizon of the Nance Syndicate oil well in Sec. 4, T. 4 N. R. 5 E., of the Doan Oil Co.'s test in Sec. 20, T. 5 N., R. 4 E., of the Transcontinental Oil Co.'s test in Sec. 14, Twp. 5 N., R. 4 E., and in the Maud Oil & Gas Co.'s oil well in Sec. 18, T. 7 N., R. 5 E., as Hunton. This is the most important contribution to the study of unconformities in Oklahoma for several years because it shows that the formations of the Arbuckle Mountains extend north of the Mountains for at least 30 miles and at that point are only 3,730 feet deep. The dip of the Hunton limestone in 16 miles is only about 1400 feet. A portion of Oklahoma formerly "condemned" now has excellent possibilities of production. The exact horizon of the unconformity between the Pennsylvanian and Devonian is not accurately determined but is possibly near the Boggy shale.

ARKOSE NORTH OF THE ARBUCKLE MOUNTAINS

Oklahoma Geological Survey Circular No. 11, by Geo. D. Morgan describes, "Arkose of the northern Arbuckle area." Arkose is found very abundantly in the Pontotoc series. It is concluded that "the base of the Pontotoc series is the time equivalent of the period at which the Arbuckle Mountains were worn down to their igneous core."

THE ASSOCIATION ROUND TABLE

A division of the columns of the Bulletin under this heading is incorporated to provide convenient opportunity for official announcements to the members of the Association, for the presentation of matters which are of importance and interest to the Association but which are outside the field of scientific or technical discussion, and for the expression and discussion by members of subjects which relate primarily to the organization, plans and business of the Association. A continuing council table at which may be considered the problems which receive all too little attention at the annual meetings and then only from a relatively small number of the members, is here contemplated.

THE SEVENTH ANNUAL MEETING OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, OKLAHOMA CITY, OKLAHOMA, MARCH 9-11, 1922.

An event of nation wide geological interest and importance is the annual meeting of the American Association of Petroleum Geologists. It would perhaps be proper to say that the event is of world wide interest for of the nearly eight hundred members of the Association many are now in foreign lands, scattered to the ends of the earth. The seventh annual meeting of the Association was held at Oklahoma City, Oklahoma, March 9th to 11th inclusive with headquarters at the Lee Huckins Hotel. For a short time all roads led toward Oklahoma City, and the number of geologists who came together to enjoy the sessions of the meeting and the pleasure of renewed associations surpassed probably that of any previous meeting of the Association. Unfortunately, a number of members who would have been present otherwise were hindered from attending on account of the time selected for the meeting, just before the 15th of March when income tax statements are due. For the benefit of those who were not able to be present at the Oklahoma City meeting a very brief and informal account of happenings may be of interest.

Registration, which as usual began on the evening before the formal beginning of the session, had accounted for a considerable number of early arrivals before Thursday morning but the greater number began to arrive Thursday morning and shortly crowded the lobby of the hotel to capacity. The business of registering members and visitors, the sale of tickets to Smoker and Banquet, and the distribution of Bulletins kept two tables busy through most of the session. Pressing business of meeting everyone else got the meeting off to a late start the first morning, but finally President G. C. Matson called the convention to order in the Elks Club Hall around the corner from the hotel. The first event was an address of welcome by the Secretary of the Oklahoma City Chamber of Commerce, Mr. Charles H. Hall, whose vigor-

ously earnest and impassioned oratory not only made all of the assembled guests feel glad that they had come, but sorry that it had been necessary to leave the family at home. Dr. Irving Perrine, President of the Oklahoma City Geological Society, cordially seconded the welcome to Oklahoma City. Acceptance and appreciation on behalf of the Association for the courteous hospitality of its hosts having been duly pronounced by the President, there was nothing to do but start the technical sessions. As to these sessions, it may be said simply that the large room of the Elks Hall was packed to near capacity through all the sessions of the three days. The papers and discussion will appear in the columns of this Bulletin. As is customary, the flow of papers rippled placidly along without interruption for certain spaces, then a swirling rapids of discussion was encountered.

Special features on the program, besides the technical sessions, were the Smoker on Thursday night, preceded by a Public Lecture, and the Banquet on Friday night. In addition quite a number of college alumni dinners and luncheons which were held should perhaps be included among the special events. The Public Lecture was given by Professor Charles Schuchert of the Department of Geology of Yale University, his subject being "The Geology of South America." The lecture was held in the commodious and beautifully appointed auditorium of the First Christian Church a short distance north of the center of town. Professor Schuchert's talk was illustrated and was thoroughly enjoyed by a very large audience. The Smoker was held in the rooms of the Oklahoma City Chamber of Commerce. The event was a decided success, for in addition to the customary functions and program of a smoker, tables with "eats" were provided and a variety of clever entertainment was offered, culminating in a song and dance act—do you remember that Doctor Ohern?—which was received hilariously.

Without doubt the most important and most interesting social event in the annals of the Association is the Annual Banquet. Those who attended the Banquet on the Mezzanine floor of the Huckins Hotel Friday evening, will long remember it pleasurably. Under the direction of Mr. Dean Stacey of the Local Committee, very attractively arranged and decorated tables had been provided, but it was found impossible in the space available to care for all who wished to attend and there were tables for the overflow just outside the main room. The Banquet was somewhat less formal than some of the annual dinners of the Association and college spirit was the chief motif in the decorations and preliminary entertainment. The decorations covered not only the tables but also the persons of many of the banqueters, caps and bandeaux of appropriate colors representing the insignia of Chicago, Wisconsin, or as the case might be, being worn by many. The amusement mentioned consisted largely of college yells and impromptu songs. One such song, the lyric of which was composed for the occasion and sung by L. J. Pepperberg and Max W. Ball was a choice bit received with special

relish. Dr. Ohern acted very ably and pleasingly as toastmaster. A beautiful but difficult violin solo, rendered in brilliant manner by Mrs. Frank Buttram began the more formal part of the program. Representing the ladies, Mrs. W. C. Kite charmingly offered a toast, which for the benefit of geologists' wives who were not present and for those who appreciate them, is presented with this account. Prof. J. B. Umpleby, of the University of Oklahoma, talked interestingly and humorously about something we have forgotten but which had to do with the number of a tank car, we believe. Prof. Charles Schuchert briefly and skillfully sketched the development of geology and of geologic research from the distant day when there really was no geology down to the present time. The supreme achievement of a very unusual evening, in the which was acquired a reputation altogether new and unexpected to his friends, but which will remain undimmed through time was the toast of James H. Gardner. There was, we think, no title but the subject had chiefly to do with Cockroaches! Who would have thought that there was any fun in a Cockroach. It is unfortunate that along with Robert Burns' "To a Louse" cannot be placed a record of a second classic, Gardner's "To a Cockroach."

A novelty was the taking of a photograph on Saturday noon of the entire convention. It was made with the aid of a specially constructed stand.

Matters of business, the election of officers (notwithstanding the pleasure of making and listening to nomination speeches), etc. will not be mentioned in this account, for that is to be handled more or less formally and officially. In closing mention may be made of the very pleasurable entertainment of the ladies which was provided.

R. C. M.

TOAST BY MRS. W. C. KITE

Mr. Toastmaster, Ladies of Faith and Geologists: The lot of a geologist's wife is one of great joys and tribulations. Perhaps this can best be shown by a series of actual telegrams exchanged between a geologist and his wife. The incidents involved might have happened to any of us.

The man of the house comes home in the evening, gets the paper off the front porch, seats himself in a comfortable chair and turns to the last page first—Ira Rinehart's Oil column—of course. Suddenly he gives a shout of excitement and rushes in to his wife, announcing, "We have made our million. The Barry test in Section 29 came in today, making 2000 barrels. We have a lease off-setting that well. I'm leaving to-night to sell that acreage."

After taking her husband to the train, the wife comes home and dreams of dozens of new hats and gowns, a big home, trips to Europe and the like.

The next day she receives the following telegram:

TELEGRAM

Marlin, Texas,

Jan 3, 1922, 1:15 P. M.

Rinehart too free with his ciphers. Well only making two barrels. Be home tomorrow.

The wife decides to get out her last year's suit and send it to the cleaners. The following day another wire comes:

TELEGRAM

Ft. Worth, Texas,

Jan. 4, 10:00 A. M.

Met President of Cheatem Oil Co. Have big deal on. Ought to make \$50,000.00. Will wire results.

The wife, in turn, sends the following message:

TELEGRAM

Oklahoma City, Okla.

Jan. 5, 3:00 P. M.

Bobby is lost, strayed or stolen. Shall I advertise?
(Bobby is the dog.)

The answer:

TELEGRAM

Ft. Worth, Texas,

Jan. 5, 6:00 P. M.

Deal blew up. Home tomorrow. Advertise.

The wife cleans house, bakes her husband's favorite cake and devises ways of cheering him up in his saddened frame of mind. Just before time to meet his train the next day comes this disappointment:

TELEGRAM

Sherwin, Texas,

Jan. 6, 11:00 A. M.

Detained several days by consulting job for Big Four Company. Address Hotel Sherwin Texas.

At this juncture the wife begins to get lonesome and misfortune attends her. The man receives the following wire:

TELEGRAM

Oklahoma City, Okla.

Jan. 6, 2:00 P. M.

Send home keys to car. Lost mine. Can't get car in garage.

She receives this reply:

TELEGRAM

Sherwin, Texas,

Jan. 6, 8:00 P. M.

Fine situation! Am sending keys. Heavy rains here. More delay.

A day or two later comes another message:

TELEGRAM

Sherwin, Texas,
Jan. 8, 9:00 A. M.

Lost tripod out of car. Must wait for new one. Home in
a few days.
And then comes an accident and the following:

TELEGRAM

Oklahoma City, Okla.

Baby cut his finger. Scared most to death. Doctor says
it will be alright. Hurry home.
The answer:

TELEGRAM

Sherwin, Texas,
Jan. 9, 5:00 P. M.

Too bad about the boy. Take good care of him. Be
here three or four days longer.
A message comes for the geologist from a client in Wichita. The
wife does not know just how to handle the affair so she sends this
telegram:

TELEGRAM

Oklahoma City, Okla.
Jan. 10, 7:00 P. M.

Smith of Wichita wires you 'Dry hole on structure you
recommended.' Shall I answer?
Reply:

TELEGRAM

Sherwin, Texas,
Jan. 11, 7:00 A. M.

Don't answer.
The wife is worried over the baby and very lonesome by this time.
To cap the climax a burglar visits the neighborhood, fortunately over-
looking the manless house, nevertheless calling forth this frantic tele-
gram:

TELEGRAM

Oklahoma City, Okla.
Jan. 13, 8:00 A. M.

Come home at once. Afraid to stay alone another min-
ute. Burglars in our block last night. Am going to
mother's.
Then comes this reply from Ft. Worth:

TELEGRAM

Ft. Worth, Texas,
Jan. 13, 3:00 P. M.

Stay there. Be home tonight 7:10 Santa Fe. Just heard
our other two wells came in today. Both dry holes."

Even if our lots do fall in lonely places and even if he is seldom here to share our joys and sorrows we are mighty proud of our geologist husbands, and always happy over the wanderer's return.

METHODS OF ELECTING OFFICERS

The Constitution Committee of the Association would appreciate suggestions and ideas from the members concerning a more desirable method of electing the officers of the Association. Many innovations have been proposed, such as that of counting first, second, and third choice, that of having ballots mailed by absent members, that of granting proxies to the absent members, that of requiring that 2, 3 or 4 nominees must be voted on for the office of President, that of having nominations published two months before the annual meeting, and several others. The present Constitution Committee has not yet met and before its first meeting it desires to digest and compare the ideas of the members of the Association.

The Committee desires to be able to make a study of the question sufficiently thorough to enable it to give wise recommendations for action by the next annual meeting.

Kindly mail your ideas to the Chairman, Chester W. Washburne, 60 Liberty Street, New York, or confer with any of the following members of the Committee: F. G. Clapp, W. E. Pratt, J. H. Gardner.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This publication does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please sent it promptly to Charles E. Decker, Norman, Oklahoma.

(Names of sponsors are placed beneath the name of each applicant)
FOR FULL MEMBERSHIP:

1. Harry L. Baldwin, Jr., Golden, Colorado.
Melvin M. Garrett
K. D. White
C. W. Washburne
2. William A. Buttram, Oklahoma City, Oklahoma.
Fred G. Rockwell
C. W. Shannon
Irving Perrine

3. James L. Chase, Billings, Montana.
S. H. Gester
Wm. L. Hubbard
J. R. Suman
4. Albert F. Cridger, Shreveport, La.
J. P. D. Hull
G. C. Branner
R. J. Riggs
5. Robert E. Garrett, Tulsa, Oklahoma.
L. B. Snider
Sidney Powers
W. B. Wilson
6. Sidney E. Mix, Shreveport, La.
J. P. D. Hull
S. C. Stathers
A. E. Hartman
7. George D. Morgan, Ada, Oklahoma.
C. W. Honess
F. G. Rockwell
C. W. Shannon
8. Herbert G. Officer, Tulsa, Oklahoma.
L. H. White
George C. Matson
R. S. McFarland
9. Horace B. Patton, Denver, Colorado.
Clyde M. Becker
Eliot Blackwelder
John L. Rich
10. C. D. Stephenson, Pawhuska, Oklahoma.
W. L. Walker
F. L. Aurin
Sidney Powers

FOR ASSOCIATE MEMBERSHIP:

1. Howell S. Clark, Okmulgee, Oklahoma.
D. W. Radcliffe
C. A. Warner
Harry Nowlan
2. George I. McFerron, Tulsa, Oklahoma.
J. V. Howell
Robert J. Davis
Robert H. Wood
3. Cornelius Schnurr, Tulsa, Oklahoma.
Richard Hughes
A. L. Beekly
Frank C. Greene

4. Rae Preece, Tulsa, Oklahoma.
Richard Hughes
A. L. Beekly
Frank C. Greene
5. Wm. H. Atkinson, Oklahoma City, Oklahoma.
Willard Miller
Wm. F. Absher
C. W. Shannon
6. Glenn O. Briscoe, Ponca City, Oklahoma.
E. L. Roark
Everett C. Parker
Walter M. Burress

A MEETING OF THE ASSOCIATION IN THE FALL

It has been the feeling of a large proportion of the members of the Association that the annual meetings of our organization should be held as conveniently near the center of petroleum geology population—if we may define that sort of population—as possible. Since a large proportion of the petroleum geologists of the country reside in the Mid-Continent and Gulf fields and since the central part of the United States is most easily reached by a majority of the members of the Association, the annual meetings have been held in Oklahoma and Texas. There are many members in the Rocky Mountain region, in the country between the Mississippi and the Appalachians, on the Pacific coast and along the Atlantic seaboard. For these, attendance at a meeting in the Mid Continent is difficult and while a number who have been present at such meetings regularly plan not to miss subsequent gatherings there are many, the majority in each of the districts outside the Mid-Continent who are denied the pleasures of the meetings.

At the meeting of the Association in Oklahoma City in March a plan to arrange for a meeting in the Fall outside of the Mid-Continent was proposed and approved. The time and place of this meeting have not been settled. A very cordial and urgent invitation from the strong group of Rocky Mountain petroleum geologists has been received to hold such a meeting in Denver. Meetings of this sort should desirably be arranged in Colorado, Wyoming, California, Illinois, Kentucky, Pennsylvania and elsewhere from time to time. The American Association of Petroleum Geologists will be strengthened by this closer contact with all parts of the country which are concerned with the finding and production of petroleum, and geologists will benefit importantly from the wider association and representation.

Watch for notice concerning the proposed meeting next Fall and plan to be present.

AT HOME AND ABROAD

MR. W. E. WRATHER will lecture at the University of Chicago from April 1st to June 15th and his address will be Rosenwald Hall. His address in Dallas, Texas, is 6044 Bryan Parkway.

MR. HEATH M. ROBINSON is now located in the Great Southern Life Building, Dallas, Texas.

MR. C. W. WASHBURN will deliver a course of lectures on petroleum geology at Harvard University during the second term. He will be assisted by Mr. K. D. White, who recently returned from Africa.

MR. E. L. JONES, JR., is Chief Geologist for the Comar Oil Company with headquarters at Ponca City, Okla.

MR. ROBERT D. GOODRICH has opened an office at 606 Linz Bldg., Dallas, Texas.

MR. JOHN FERGUSON is geologist for the Borealis Oil Co., of Oklahoma City, Okla.

MR. D. R. SNOW is Chief Geologist for Waite Phillips in the Petroleum Building, Tulsa, Okla.

MR. W. S. W. KEW, of the U. S. Geological Survey is mapping the Palo Verde Hills near San Pedro, Southern California.

MR. O. L. BRACE is employed by Mr. Ralph Arnold at Los Angeles, Calif.

MR. GLEN M. RUBY is working in Utah.

MR. J. E. ELLIOTT, formerly of the Shell Company, and F. C. MERRITT, have opened an office as Consulting Geologists in Los Angeles, Calif. Mr. Elliott is specializing in examination of core samples.

MR. A. M. MACKENZIE, formerly with the Gypsy Oil Co., is spending the winter at Leland Stanford University.

MR. W. R. HAMILTON is President of the Hamilton Oil Corporation which has superseded the Oil Issues Co.

MR. W. A. VER WIEBE has been in New York City on a business trip.

MR. E. B. HOPKINS is in South America.

MR. W. F. ABSHER is Geologist for the Norman Oil Syndicate at Norman, Okla.

PROF. ELIOT BLACKWELDER will spend the summer at Iola, Kansas, and in the fall will take up his work as Professor of Geology at Leland Stanford University.

MR. F. B. ELY is working in Mexico and his address is Apartado 5314, Mexico City.

MR. W. S. ADKINS is Paleontologist for the Mexican Eagle Oil Co., at Tampico, Mexico.

PROF. J. T. SINGLEWALD, JR., has been in Mexico for the interests of the Standard Oil Co.

MR. A. W. DUSTON is President and **MR. C. Z. LOGAN**, Secretary-Treasurer of the Okmulgee Geological Society.

MR. J. Q. MYERS is living in Tulsa, Oklahoma, and his address is 413 Mayo Bldg.

MR. L. L. HUTCHISON is now located at 203 Atco Bldg., Tulsa, Okla.

MR. C. W. PURDY has returned from South America.

MR. W. M. SMALL has returned from Mexico for a visit.

MR. E. EGGLESTON SMITH is in the United States on a visit.

RESEARCH SERVICE, 100 Lexington Ave., New York City, has been organized for bibliographic service, translation of articles in foreign languages, and all kinds of research. Orders are taken for foreign and domestic maps and geological publication.

MR. RALPH ARNOLD is President and **MR. CHARLES WAGNER**, Secretary of the Branner Club of Southern California which meets in Los Angeles every three weeks.

MR. J. P. D. HULL is Chairman and **MR. J. O. NELSON** Secretary of the Shreveport Section of the Southwestern Geological Society.

MR. ROBERT J. RIGGS made the location for the well of Campbell, et al. in Sec. 8, T. 13 N., R. 15 E., Okmulgee Co., Oklahoma.

MR. C. A. WARNER represents the Houston Oil Co. at Okmulgee, Okla.

MR. L. J. YOUNGS has resigned from the Oklahoma Producing & Refining Corporation and is now with the Gypsy Oil Co., at Tulsa, Okla.

MR. V. O. TANSEY is with the Gypsy Oil Co., at Tulsa, Oklahoma.

MR. HERBERT SHELTON is Chief Geologist for the Buckley Interests in Mexico, working under the direction of Mr. Ben C. Belt.

MR. W. F. BOWMAN is with the Rio Bravo Oil Co., at Houston, Texas.

MR. O. E. HANS is with the Phillips Petroleum Co., at Bartlesville, Okla.

MR. T. C. LINDERFELT is Chief Geologist for the Rood Oil Corporation of Bartlesville, Okla.

MR. A. O. DOVRE is Chief Geologist for the Venezuelan Sun Co., Ltd., with headquarters at Maracaibo, Venezuela.

THE THIRTEENTH SESSION OF THE INTERNATIONAL GEOLOGICAL CONGRESS will be held at Bruxelles, Belgium, August 10th to 19th, 1922. The first excursions, commencing August 1st will illustrate the geology of Belgium. The second excursions are for one day only and are held during the session. Additional excursions with a maximum duration of 12 days follow the meeting. Professor A. Renier, of the University of Liege, Bruxelles, is the Secretary General.

THE WICHITA GEOLOGICAL CLUB has recently been organized at Wichita, Kansas, membership in which is limited to those who are eligible to membership in the American Association of Petroleum Geologists. There is at present possibility of some 35 to 40 members in and around Wichita. The officers of the Club for the present year are **ROY S. HAZELTON**, *President*, **HERMAN J. ALLEN** and **WILLIAM AINSWORTH**, *Vice-Presidents*, and **A. I. LEVORSEN**, *Secretary-Treasurer*. Meetings are held at least once a month and it is the plan of the Club to make them as informal as possible.

MR. DONALD MCARTHUR is engaged in foreign exploration work for the Tropical Oil Company, with present address as Cartagena, Colombia.

MR. FRANK B. NOTESTEIN is engaged in exploration work in Egypt.

MR. THERON WASSON and **MR. JOSEPH H. SINCLAIR** recently returned to the United States from Ecuador. Mr. Wasson has been made Chief Geologist of the Pure Oil Company, with headquarters at Tulsa, Okla. Mr. Sinclair will be associated with Mr. E. B. Hopkins at 25 Broadway, New York City.

MR. HARRY J. BROWN, Chief Geologist of the Pierce Oil Corporation, is now located in the Wagonner Building at Fort Worth, Texas.

MR. E. E. LINDEBLAD has returned to the Empire Gas & Fuel Company and will work in Kansas.

MR. J. W. MERRITT is Chief Geologist for the Freeborn Engineering Company of Tulsa, Oklahoma.

MR. L. B. BENTON, of the Humble Oil & Refining Company, has returned from Houston to Ardmore, Oklahoma.

MR. MAX A. PISCHEL is Consulting Geologist for the Mid-Co. Pet. Company in Tulsa and has his office at 1046 Kennedy Bldg.

MR. E. W. HUMMEL has been in South America.

The firm of **EATON AND LOOMIS** has been dissolved. Mr. Harve Loomis will continue his practice as Consulting Geologist at 812 American National Bank Building, Oklahoma City, Okla.

MR. F. G. CLAPP, of New York City, recently made a trip through the Mid-Continent fields.

MR. FRANK EDSON has returned from Mexico and is at Norman, Okla.

MR. MAX W. BALL, of Denver, Colorado, is President of the newly formed Rocky Mountain Geological Society.

MR. MYRON L. FULLER is on a pleasure trip in Europe

MR. E. L. ESTABROOK published a paper entitled: "Production problems in the Grass Creek oil field," in the February number of *Mining and Metallurgy*.

MR. GEORGE C. MATSON, General Manager of the Schermerhorn Oil Co., has his office at 408 Cosden Bldg., Tulsa, Okla.

THE SHREVEPORT SECTION OF THE SOUTHWESTERN GEOLOGICAL SOCIETY is backing a movement to reestablish a geological survey in Louisiana with the Professor of Geology at the State University as Director. At the present time there is no geological department at the University. The committee which is drafting a bill for the legislature consists of Clyde M. Bennett, John Y. Snyder, and Ben K. Stroud.

MR. MORRIS E. MORTIMER is in South America for The Texas Co.

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We have arranged for a good amount of advertising for the next issue. We hope that the members will justify our representations and encourage further support of our publication, first, by endeavoring to secure your requirements from those who advertise in this Bulletin, and second, by calling the advertiser's attention to that fact whenever an order is placed.

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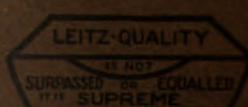
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VOLUME 6

NUMBER 3

BULLETIN
OF THE
AMERICAN ASSOCIATION
OF
PETROLEUM GEOLOGISTS

RAYMOND C. MOORE,
Editor

Department of
Mineralogy & Petrography
HARVARD UNIVERSITY
CAMBRIDGE, MASS.

MAY-JUNE, 1922

LAWRENCE, KANSAS

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VOLUME VI

NUMBER 3

BULLETIN
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RAYMOND C. MOORE
Editor

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MAY—JUNE, 1922

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

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CONTENTS

A Review of Oil and Gas Pools in North Louisiana Territory	179
By J. P. D. Hull and W. C. Spooner	
The El Dorado, Arkansas, Oil Field and Its Relation to North Louisiana Structures.....	193
By A. F. Crider	
Discussion	
Stratigraphy of a Part of Southern Utah.....	199
By Raymond C. Moore	
Discussion	
Rock Distortion on Local Structures in the Oil Fields of Oklahoma.....	228
By James H. Gardner	
Discussion	
GEOLOGICAL NOTES	244
Possible Oil in Southern Utah, <i>Raymond C. Moore</i> ; The Bellevue Pool, Louisiana, <i>J. P. D. Hull</i> ; Webster Parish Gas Field, Louisiana, <i>J. P. D. Hull</i> ; A New Gulf Coast Dome, <i>Wallace E. Pratt</i> ; A Schedule for the Field Description of Sedimentary Rocks; Note on "A Review of Oil and Gas Pools in North Louisiana Territory," <i>Wallace E. Pratt</i> .	
REVIEWS AND NEW PUBLICATIONS.....	260
THE ASSOCIATION ROUND TABLE.....	266
Proceedings of the Seventh Annual Meeting of the American Association of Petroleum Geologists held in Oklahoma City;	

Bull. Am. Assn. Petrol. Geol.

**Secretary-Treasurer's Report; *C. E. Decker*; Election of Officers,
C. W. Washburne; Membership Applications Approved for Publication.**

AT HOME AND ABROAD..... 276

Current News and Personal Items of the Profession.

BULLETIN
OF THE
AMERICAN ASSOCIATION
OF
PETROLEUM GEOLOGISTS

MAY—JUNE, 1922

A REVIEW OF OIL AND GAS POOLS IN NORTH LOUISIANA TERRITORY

J. P. D. HULL AND W. C. SPOONER

INTRODUCTION

Natural gas was first recognized in seeps near Red River in Caddo Parish, Louisiana, many years ago, a long time before wells were drilled in that territory for oil or gas. The development of Caddo, the first oil and gas pool, did not begin, however, until 1904. In 1912 and 1913 gas and oil were discovered in commercial quantities in De Soto Parish, and since that time many pools have been found and prospects are bright for the discovery of many more.

The Louisiana State Geological Survey began collecting information on oil and gas prior to 1900, but owing to lack of funds, continuous work has been impossible; in fact there has been no State Survey for more than a decade, since Prof. G. D. Harris of Cornell University had charge of the Louisiana work.

Four publications of the U. S Geological Survey furnish the principal geological information used as a basis for work in the North Louisiana-South Arkansas fields, namely; Veatch's "Geology and Underground Water Resources of Northern Louisiana and Southern Arkansas," Professional Paper 46, 1906, Harris' "Oil and Gas in Louisiana," with a Brief Summary of their Occurrence in

J. P. D. Hull, Geologist, Louisiana Oil & Refining Co., Shreveport, La.

W. C. Spooner, Geologist, Arkansas Natural Gas Co., Shreveport, La.

Adjacent States", Bulletin 429, 1910, Matson's "The Caddo Oil and Gas Field, Louisiana and Texas", Bulletin 619, 1916, and Matson and Hopkins', "The De Scto-Red River Oil and Gas Field, Louisiana", Bulletin 661-C, 1917.

Three more recent publications are "The Sabine Uplift, Louisiana", by Sidney Powers, Bulletin American Association Petroleum Geologists, Vol. 4, No. 2, 1920, "The Monroe Gas Field, Ouachita, Morehouse and Union Parishes, Louisiana", by H. W. Bell and R. A. Cattell, U. S. Bureau of Mines, published July, 1921, as Bulletin 9 of the Department of Conservation, State of Louisiana, and "The Haynesville Oil Field, Claiborne Parish, Louisiana", by W. W. Scott and Ben K. Stroud, published as Bulletin 11 of the State Department of Conservation in co-operation with the U. S. Bureau of Mines, Jan., 1922.

GENERAL GEOLOGY

The area here designated "North Louisiana Territory" covers the adjacent parts of East Texas to include the Bethany gas pool and the adjacent parts of South Arkansas to include the El Dorado oil and gas pool. The southern limit of the area may be considered as latitude 31° North corresponding with Veatch's map¹.

The following table shows the sequence of formations in this territory:

Table of Formations

System	Series	Group	Formation
Quaternary	Recent		
	Pleistocene		Port Hudson
	Pliocene		Lafayette
Tertiary	Oligocene		Fleming Clay
			Catahoula
			Vicksburg
			Jackson
	Eocene	Claiborne	Cockfield
			St. Maurice
			Wilcox
			Midway

¹Veatch, A. C., U. S. Geol. Survey, Prof. Paper 46.

Cretaceous	Gulf (Upper Cretaceous)	Austin	Arkadelphia Clay
			Nacatoch Sand
			Marlbrook Marl
		Bingen	Annona Chalk
			Brownstown Marl
			Blossom Sand
	Comanche (Lower Cretaceous)	Washita	Eagle Ford Clay
			Woodbine Sand
			Denison
		Fredericksburg	Fort Worth Limestone
			Preston
		Trinity	Goodland Limestone

The surface formations over the oil and gas pools in the Louisiana-Texas-Arkansas territory are restricted to the Eocene and Pliocene series of the Tertiary system, and the Pleistocene and Recent series of the Quaternary system, except the Cretaceous outcrops on the several truncated salt domes. These unconsolidated sediments, Wilcox, St. Maurice, Cockfield, Lafayette, and Port Hudson, have distinctive features where typically developed, but they are commonly indistinguishable one from another because of their origin from similar sources and because of subsequent reworking.

STRUCTURE

Practically all of the formations penetrated by the drill in North Louisiana outcrop in Arkansas within 100 miles, more or less, north and northwest of the pools. The regional dip is south and southeast from the Ouachita Mountain Uplift to the Gulf of Mexico and Mississippi River. The Cretaceous deposits rest on the eroded Paleozoic floor at a very gentle angle of dip where undisturbed by deformation, but these undisturbed places representing most closely the original deposition are almost the exception to the rule, for the whole region is marked by uplifts, domes, folds, and faults with accom-

panying synclines and troughs which all together make a sub-surface contour map of rugged and broken appearance.

A line on top of the Nacatoch formation drawn southeast from the outcrop in Arkansas drops about 2370 feet in 57 miles (41 feet per mile) to the Louisiana state line; rises 300 feet in 8 miles to the top of the Haynesville structure; drops 100 feet in 10 miles between Haynesville and Homer; rises 1000 feet in 5 miles to the top of the Homer dome; and going farther south, drops 1200 feet in 5 miles, or 240 feet per mile, east of Minden.

These distinct uplifts and domes which are considered as structural deviations from the normally gentle regional dip may be described in four groups and classified as: (1) Sabine Uplift, (2) Ouachita Uplift, (3) Isolated Domal Structures and (4) Eroded Salt domes.

The Sabine Peninsula, or Uplift, was described as such by Harris² in 1907 and 1910.

A recent paper by Sidney Powers³ was published in the Bulletin of this Association in 1920. The uplift occupies the northwestern part of the state, including the parishes of Caddo, Bossier, De Soto, and Red River, and extending across the state line into Marion, Harrison, Panola, and Shelby counties, Texas. On this structural uplift are the Caddo oil and gas pool, Shreveport gas pool, Elm Grove gas pool, De Soto-Red River oil and gas pool, Bethany gas pool, and Bellevue oil pool.

The Ouachita Uplift is much less extensive than the Sabine Uplift and not such a high structure. It includes parts of Ouachita, Morehouse, and Union parishes in the northeastern part of Louisiana, 75 miles east of the Sabine Uplift. The Monroe gas pool is on the Ouachita Uplift.

There are three isolated folds and domes between the two large uplifts: Homer, Haynesville, and El Dorado. These will be described separately.

The fourth group of pronounced domes comprises the sa-

²Harris, G. D., Rock Salt in Louisiana, Geol. Survey of La., Bull. 7, 1907, Pl. 24; Oil and Gas in Louisiana, U. S. Geol. Survey, Bull. 429, 1910.

³Powers, Sidney, The Sabine Uplift, Louisiana, Am. Assn. Petrol. Geol., Bull., Vol. 4, No. 2, 1920.

lines, or salt works, rising from synclines between the two large uplifts and south of the isolated productive domes and folds. The salines are eroded, non-productive, steeply dipping domes in Bossier, Bienville, Natchitoches, and Winn parishes.

STRUCTURAL EVIDENCE

In working out sub-surface Cretaceous structure in advance of drilling beneath an area made up of unconsolidated Tertiary deposits mantled by Quaternary and Recent sands and clays, the geologist must consider the possible evidence of everything in sight and then be ready to discard all of it when subsequent drilling disproves it.

The surface features he generally considers in mapping wild cat areas are stratification, dips, inliers, topography, stream courses, springs, and vegetation, besides the stratigraphy and petrology of the formations.

When it is known that most of the production comes from depths ranging from 1500 to 3000 feet in Cretaceous beds that are separated from the surface by erosional unconformities, overlaps, faults, and lens pinching, it is not surprising that some geologists have considered the unconsolidated cross-bedded surface as worthless in attempting to determine structure. Nevertheless judicious use of these surface indications has enabled geologists to locate a number of valuable producing structures such as Haynesville which is less than a year old in March 1922 is producing about 90,000 barrels a day and is less than one fourth drilled up, exclusive of at least two sands still to be tested.

OIL POOLS

CADDO POOL

The Caddo oil and gas pool may be called a field in which there are several pools. The south end of the field is at Mooringsport, 15 miles northwest of Shreveport. Its area is about 180 square miles on the northern end of the Sabine Uplift. Like many other parts of the uplift it possesses no topography peculiarly distinctive of an uplift or favorable oil structure. Much of the surface is swamp land and lake bottom, though the rolling hills rise 180 feet above Caddo Lake. The surface

geology is on the whole non-committal Wilcox and Quaternary. Gas seeps caused the search for oil and gas and drilling found the structure. It is one of the higher parts of the Sabine Uplift but has a structural relief of only 200 feet. The field is spotted irregularly, probably because of small local folds and faults that are impossible of determination except by drilling.

Caddo produced the first gas in Louisiana,—from the Nacatoch sand from 800 to 1,000 feet below the surface. Oil is produced from the Woodbine sand from depths of 2,200 to 2,275 feet, and from the Trinity formation at 2,900 feet, more or less. Caddo's production dropped from 10,000,000 barrels in 1913 to 6,000,000 barrels in 1917, but in 1918 development in the Pine Island pool raised the output to 11,000,000 barrels. In 1921, the production was again below 6,000,000 barrels but the Trinity formation in the same Pine Island district is now providing a new source of high gravity oil and Caddo still has surprises to bring forth, as the field is by no means drilled up. It has produced to date (1906 through 1921) 86,450,848 barrels, exclusive of fuel oil. It has been estimated that Caddo has an ultimate production of 122,000,000 barrels of which 118,000,000 are probable and 4,000,000 are possible.

DE SOTO-RED RIVER POOL

The De Soto-Red River pool is 45 miles southeast of the Caddo pool, at the southeast end of the Sabine Uplift. It is on both sides of Red River in De Soto and Red River parishes. The topography, areal and structural geology, and drilling conditions are almost the same as in the Caddo pool, except that the pool is divided by a fault with a 200-foot down-throw to the south. Gas occurs in the Nacatoch, but practically all of the oil has been produced from the Woodbine, which lies at a depth of 2,500 to 2,700 feet. The field has produced (1914 through 1921) 37,837,360 barrels, less than half the amount of Caddo. The ultimate yield is estimated as 63,000,000 barrels of which 60,000,000 are probable and 3,000,000 are possible.

BELLEVUE POOL

The Bellevue pool is not only the newest pool on the Sabine Uplift but it is also the youngest oil pool in the North Louis-

iana territory. It is at the northeastern edge of the Uplift, in Bossier Parish, 15 miles northeast of Shreveport. The surface is almost flat with a general elevation of 215 feet above sea level, and appears to be quite the opposite to what it really is, the highest productive structure in the region.

Although bedding planes for structural mapping are scarce and doubtfully dependable, the surface geology is more clearly indicative of sub-surface structure here than in almost any other North Louisiana pool, excepting the eroded salines. True, it has required years to locate the high part of the dome, but this structural inlier has been known in print since 1905 when it was mapped by Veatch.⁴ A stratigraphic sequence of Eocene formations may be followed from older Wilcox outward through overlying St. Maurice and Cockfield of the Claiborne formation to the younger Quaternary sands surrounding the pool, thus exhibiting a truncated dome whose exposed top occupies a whole township of 36 square miles.

The productive part, however, as developed to date, underlies but one square mile. Oil of about 20 gravity flows from the Nacatoch sand from depths as shallow as 63 feet below sea level or 290 feet below surface. Some gas also occurs with the oil.

The Bellevue structure has a relief of 700 feet on top of the Sabine Uplift, forming an exceptionally high dome on the end of a nose eastward from the main part of the uplift. On its east side, however, the Bellevue dome drops 1,800 feet in 6 miles to a deep syncline southwest of the Homer pool. This is the highest productive dome in the North Louisiana territory where the Cretaceous sands are sealed. It is more than 600 feet higher than Homer, both referred to sea level. It is, therefore, an ideal place to test each of the four Cretaceous sands known to be productive elsewhere in the territory, namely; Nacatoch, Blossom, Woodbine, and Trinity. Only one hole has been drilled into all these formations and it did not find production, though it went to a depth of 4,052 feet. This was

⁴Veatch, A. C., *Geology and Underground Water Resources of Northern Louisiana and Southern Arkansas*, U. S. Geol. Survey, Prof. Paper 46, Pl. III, 1905.

drilled by the Texas Company on the southwest slope of the structure.

Bellevue was discovered to be commercially productive in November, 1921, by R. O. Roy's persistence in drilling and by J. Y. Snyder's insistence in geology. About 15 wells have perhaps more than 50,000 barrels of 20 gravity oil in storage awaiting completion of the Standard Oil Company's pipe line. If production corresponds with the size of the dome and accessibility of the sands. Bellevue should have an ultimate production of 41,500,000 barrels.

HOMER POOL

The Homer pool was the first pool discovered off the Sabine Uplift, in 1919. It is in the western part of Claiborne Parish, 45 miles northeast of Shreveport, and underlies an area of 5 square miles.

Homer is one of the three isolated domes (El Dorado, Arkansas, and Haynesville, Louisiana, being the other two) having topographical and geological conditions different from the pools on the Sabine Uplift. It is a distinct structural dome approximately underlying a topographically high surface which is not only an interstream ridge but is a high divide from which there is drainage in all directions.

The rolling to hilly surface ranges from 225 to 325 feet above sea level. The surface formations are either Wilcox or Claiborne with some exposures of stratification that indicate an uplift. Sub-surface structure based on the Nacatoch sand shows a structural relief of 1,200 feet, from 700 feet below sea level on top of the dome to 1,900 feet 5 miles south of this point. The dome is broken east and west through the center by a fault with a downthrow of 300 to 400 feet on the south side. Both Nacatoch and Blossom sands, separated from each other by an interval of 700 feet, produce at Homer. The pool is practically drilled up, though the Woodbine sand has been tested in only a few places by deeper drilling. Though only 3 years old, Homer has produced 37,639,251 barrels, or as much as the De Soto-Red River pool, that is 8 years old. It is estimated that Homer has an ultimate production of 64,000,000 barrels.

EL DORADO POOL

The El Dorado pool is situated in the central part of Union County, Arkansas, and lies approximately 25 miles northeast of the Haynesville pool. The proven oil and gas area comprises 20 square miles, or 12,800 acres.

The topography of the region is very similar to that of Northern Louisiana, the surface features ranging in elevation from 100 feet, on the wide valley floor of Ouachita River, to about 300 feet on the hill summits.

The strata exposed consist chiefly of soft clays, sands, lignites, and gravels of Tertiary age. Superficial deposits of the Quaternary period cover the valley floors of Ouachita River and smaller streams. The section includes the Upper Claiborne formations of the Eocene Tertiary to the Nacatoch sand of the Upper Cretaceous found at an average depth of 2,150 feet.

Surface structure is very misleading. The Pleistocene covering the Tertiary deposits renders the work on clays, gravels, and lignites very doubtful. Reversals show surface structures which do not check the sub-surface conditions.

Sub-surface structure is based on top of the Nacatoch or producing horizon. In general it has a north-south trend dipping to the east. Since no particular structure is depicted by means of reversals, accumulation here is principally accounted for by sand conditions. From drilling records to date the sand seems to grade into shales from east to west.

Five-foot contours drawn within the approximate forty-foot dip in the producing horizon show the area to be noticeably disturbed. The pay sand which is principally a sandy shale ranges from one to thirty feet in thickness accompanied by a bad water and basic sediment content also very variable.

Development so far has covered a proven area of 12,000 acres. To date there have been 1,249 locations made of which 757 have come in as producers, 222 are either dry or drilling below 2,100 feet, and 270 are spudded.

Of the producers nearly all were oil wells with either a little or no gas and with varying amounts of water and basic sediment. The initial production of wells falls off very fast due to

these conditions. There are a few scattered gas wells.

Total amount of shipments and storage for the year 1921 commencing March 24th was 10,819,265 barrels. The oil has a gravity of 33.8 degrees Baume.

HAYNESVILLE POOL

The Haynesville pool comprises an area of about 8 square miles in T. 23 N., R. 8 W., Claiborne Parish, just south of the Louisiana-Arkansas state line. It is 50 miles northeast of Shreveport and 12 miles north of the Homer pool. The surface is an interstream divide with a local relief in the field of 100 feet, ranging from 260 to 360 feet above sea level.

The formations exposed are Upper Claiborne (Cockfield) and the common Quaternary mantle of sand and gravel. The exposures of Cockfield sandy clays show a remarkable number of dips which outline the underlying structure on the producing sand (Blossom).

Haynesville is a pronounced but low structure as compared with Homer, being 900 feet lower and having a relief of only 300 feet on the Nacatoch as compared with 1,200 at Homer. Contours on the producing Blossom sand show a local relief of 80 feet in the producing area. No well-recognized fault has yet been found.

Since the spring of 1921, more than 200 wells have been drilled. These now produce 90,000 barrels per day. The field as developed in the Blossom sand is less than one fourth drilled up, has produced about 6,000,000 barrels of high gravity oil and is probably good for an ultimate production of 57,000,000.

The field has been well described by W. W. Scott and Ben K. Stroud.⁵

GAS POOLS

The more notable developments of gas territory in North Louisiana during 1921 have been the discovery of gas in Webster parish and the extension of the Monroe gas pool.

CADDO POOL

The Caddo pool takes its name from the parish wherein located. It is divided into several districts of which the Vivian

⁵Scott, W. W., and Stroud, Ben K., The Haynesville Oil Field, Claiborne Parish, Louisiana, Bull. 11, State of Louisiana Dept. of Conservation, in co-operation with the U. S. Bureau of Mines, January, 1922.

district in T. 22 N., R. 15 W., and the Oil City district in T. 20 N., Rs. 15 and 16 W., are the more important gas producing areas.

The Nacatoch sand at a depth of 800 to 1,000 feet is the important gas producing horizon.

During the early years of development in the Caddo field a vast volume of gas was wasted through improper drilling and wasteful methods of operation. In 1910, the first year of which records were available, the rock pressure had declined to 190 pounds; 20 pounds in 1920; 14 pounds in 1921; and 10 pounds January 1st, 1922, nearly making the depletion of the pool.

The gas available before completely exhausted probably does not exceed one billion cubic feet.

ELM GROVE POOL

This pool, also known as the Bossier pool, is situated in T. 16 N., Rs. 11 and 12 W., Bossier Parish.

The Wilcox formation is found at the surface throughout the field. Two sands are productive; the Nacatoch sand from a depth of 800 to 900 feet and the Woodbine sand from a depth of 2,450 to 2,550 feet. Neither sand is productive throughout the pool. The Nacatoch production is confined principally to the western part of the pool, while the Woodbine production is principally on the east side.

The surface dips in the Wilcox indicate a structure, but it is by sub-surface work only, that the structure can be outlined with any degree of accuracy. Based on the Nacatoch sand the structure takes the form of a dome slightly elongated northeast and southwest. Production is obtained as low as 70 feet down the dip from the apex of the dome.

About 160 wells have been drilled in this field, 31 of which were dry holes. At the present time, there are 51 active wells, 28 producing from the Nacatoch and 23 from the Woodbine sand.

The initial rock pressure was 1,100 pounds for the Woodbine and 400 pounds for the Nacatoch, while the present rock pressure is 305 pounds and 245 pounds respectively for these sands.

To January 1st, 1922, the Nacatoch sand had produced 36,-

000,000,000 cubic feet and the Woodbine sand 51,000,000,000 cubic feet.

The reserve gas remaining in the field is estimated as approximately 50,000,000,000 cubic feet.

BETHANY GAS POOL

This pool is situated mainly in Panola County, Texas, but also includes a part of Harrison County, Texas, and Caddo Parish, Louisiana.

The Wilcox formation is exposed at the surface. Four different sands produce the gas, as follows:

Nacatoch sand at an average depth of 1,500 feet.

Blossom sand at an average depth of 1,725 feet.

Woodbine sand at an average depth of 2,650 feet.

Deep Gas sand at an average depth of 2,950 feet.

The Nacatoch sand production appears to extend throughout the pool; the Woodbine sand production is limited to the southern part; the deep sand has been developed only in the northern part; and the Blossom sand to this time has been developed only in the western part of the pool. Future development may prove the Blossom sand production to extend over a considerable area.

The surface dips in connection with the topography and drainage indicate a structural high in this area. Sub-surface mapping shows a northeast-southwest trending anticline with a superimposed dome on the north end and one on the south end. Additional data will probably show a sub-surface fault between the two domes.

To date 52 wells have been drilled in this pool, 22 of which are gas wells and the remainder dry holes or small abandoned oil wells. The gas wells are producing from the different sands as follows: Nacatoch sand 6 wells, Blossom sand 3 wells, Woodbine sand 7 wells, Deep gas sand 6 wells. The initial rock pressure was 450 pounds for Nacatoch sand, 840 pounds for Blossom sand, 1,050 pounds for Woodbine sand and 1,200 pounds for Deep gas sand.

Up to January 1st, 1922, gas had been taken only from the north part of the pool and 810,000,000 cubic feet had been removed from the Nacatoch and 3,150,000,000 cubic feet from

the Deep gas sand. In the corresponding time the rock pressure declined to 200 pounds for the Nacatoch and 300 pounds for the Deep sand.

The wells producing from the Woodbine and Blossom sands have not been connected to the pipe line and no information is available as to the future life of these wells.

It is estimated that Bethany will produce 75,000,000,000 cubic feet of gas before depleted.

MONROE GAS POOL

This pool covers an area of more than 250 square miles in Union, Morehouse, and Ouachita parishes. It is about 110 miles east of Shreveport, Louisiana. The greatest development to date has been in T. 19 N., R. 4 E., and T. 20 N., R. 4 E.

Along Ouachita River and Bayou Bartholemew the average surface elevation is 80 feet. West of Ouachita River the elevation increases to 150 feet.

The larger part of the Monroe gas pool is covered with recent formations of Pleistocene and Quaternary age. In a few places rocks of Eocene age are found, but due to the lithologic similarity of the Eocene formations, it is difficult to determine their exact age.

Sub-surface geology based on well logs indicates an uplift in this region comparable in magnitude to the Sabine Uplift in the western part of the state. This uplift, which has been termed the Ouachita Uplift, trends in the same general direction as the Sabine Uplift. Local domes elongated northeast and southwest are superimposed upon the major fold. Drilling to date has not defined the limits of this uplift.

The production is obtained from a depth of 2,000 to 2,300 feet from an horizon similar to the Annona Chalk. The initial rock pressure was 1,050 pounds.

About 143 wells have been drilled and 82 are producing gas wells. It is estimated by the Department of Conservation of Louisiana that 110,000,000,000 cubic feet have been used and lost through wild wells. In Bulletin 209 published by the Department of Conservation, H. W. Bell and R. A. Cattell estimate the total volume of gas in the field at 4,750,000,000,000 cubic feet.

WEBSTER PARISH

The area of particular interest owing to recent completions of gas wells is that part of Webster Parish comprising T. 23 N., Rs. 9, 10 and 11 W. The topography and geology of this area is similar to that of the Haynesville oil pool immediately to the east.

Three producing gas wells have been completed in this area as follows: in 20-23-9, Sinclair Oil Co.'s Mayfield No. 1, 7 mil.; in 34-23-11, Lloyd Harris et al., Pine Woods No. 1, not gauged; and in 1-22-10, Portland Synd., Munn No. 1, 44 mil. Dry holes have been drilled in all directions from these producing wells, but not in sufficient numbers to determine the probable producing area which, however, appears to be large. The production is from the Blossom sand as at Haynesville.

OTHER GAS PRODUCING AREAS

The Shreveport-Cross Lake pool situated in T. 18 N., R. 14 W., and T. 17 N., R. 14 W., is partially depleted as is also the Cedar Grove pool in T. 17 N., R. 13 W.

The Red River-De Soto pool is practically depleted, furnishing only enough gas for field use.

SUMMARY

After watching new oil and gas pools come in one after another in the North Louisiana-East Texas-South Arkansas territory, the observer is greatly encouraged in looking for new pools beneath the large areas in these states where wildcatting is only beginning to be done.

A tabulated summary of the pools and their production is given below:

Summary of pools and pipeline runs in the North Louisiana Territory to January 1, 1922

Pools	Age (Years)	Acreage Drilled	Barrels Pipeline Runs	Barrels per Acre
Caddo	16	31,000	86,500,848	2,790
De Soto-Red River	8	10,000	37,837,360	3,783
Homer	3	3,000	37,639,251	12,546
El Dorado	$\frac{3}{4}$	4,000	10,500,000	2,625
Haynesville	$\frac{2}{3}$	1,400	3,000,000	2,142
Total		49,400	175,477,459	3,552

THE ELDORADO ARKANSAS OIL FIELD AND ITS RELATION TO NORTH LOUISIANA STRUCTURES.

A. F. CRIDER

INTRODUCTION

For a number of years the state line between Arkansas and Louisiana was fixed in the minds of the majority of oil operators, and not a few geologists, as the boundary between productive and non-productive oil and gas territory. This idea did not develop without some basis for the conception. Some of the first geologic reports, by the best of authorities, separated the two areas by a pronounced fault. The oil-bearing horizons on the north side of this fault were believed to be in a low regional syncline and would contain salt water instead of oil or gas. The first wells drilled on the Arkansas side rather strengthened this general belief.

It took the cooperation of the geologist and the operator to overcome this prejudice, and to give this region the consideration it deserves. It is an item of scientific interest that the first producing oil field of Arkansas was discovered and recommended by a geologist, Mr. J. J. Victor. His conclusions were concurred in by other geologists who recommended the territory to their respective companies, and by Mr. K. C. Heald, of the U. S. Geological Survey.

It is not known what led Mr. Victor and the other geologists to look for a structure at ElDorado. They no doubt believed that the same forces that produced the primary and secondary folding of the Osage district in Oklahoma, and produced the structures at more or less regular intervals, operated in the Coastal Plain formations under modified conditions, and after determining the checkerboard system of folding in the producing fields in Louisiana it was a logical place to look for a fold.

STRATIGRAPHIC SECTION

It is not the purpose of this paper to discuss the extent and operating conditions of the ElDorado field. However, a few words in regard to the stratigraphy and the nature of the

structure will not be irrelevant to the subject matter under discussion. Various opinions have been expressed as to the stratigraphic horizon of the producing sand in the Eldorado field. A study of the Eldorado logs shows the Wilcox formation to extend to a depth of 1200 to 1300 feet. The base of the Wilcox is well defined by a bed of lignite in most of the wells. Below this comes 150 to 200 feet of limestone, shale, and marls of Midway age. The Midway forms the most striking key horizon of north Louisiana and South Arkansas oil territory. The Midway outcrops near Benton, Arkansas, about 90 miles north of Eldorado.

Directly underlying the Midway comes 500 to 600 feet of Arkadelphia shales of a dark color at the outcrop but light grey in some places in Louisiana.

The interval between the base of the Wilcox and the producing sand in the Eldorado field is 800 to 900 feet. This corresponds approximately to the interval between the Wilcox and the Nacatoch horizon in north Louisiana. A hard limestone, about 150 feet above the producing sand, forms a distinctive marker for the driller in determining the position of the pay sand.

Fossils obtained from some of the wells and a study of some of the minute forms from cuttings, point conclusively to the Nacatoch age of the Eldorado producing sand.¹

Below the Nacatoch sand comes about 900 feet of chalk, shales and sands of Annona and Brownstown age. At a depth of 3000 feet, in the Cooper Henderson well, on the Hammond farm in Sec. 19, T. 17 S., R. 15 W., a bed of sand and gravel was encountered which apparently marks the base of the Upper Cretaceous.

The gravels from this horizon are mostly quartzite and chert, and range from large sand grains to pebbles one inch or more in diameter. They are associated with pink shales and the gravels themselves have decided pink color when broken open. These gravels are not present at this horizon

¹Since this paper was written, in a press Bulletin issued by the U. S. Geological Survey, Mr. L. W. Stephenson states that fossils, sent him by Mr. H. N. Spofford of the Gladys Belle Company of Eldorado, from the producing horizon, are of undoubted Nacatoch age.

throughout north Louisiana and south Arkansas. They have been reported in a number of wells but no samples other than those from the Cooper Henderson well have been examined by the writer.

The pink clays and sands similar to those associated with the red gravels in the Cooper Henderson well have been found approximately 300 feet below the gas sand in the Monroe field. They have likewise been found to underlie the Bull Bayou, Bethany, Caddo, the shallow Bossier, and Homer fields. These pink or red shales are believed to represent the Lower Cretaceous here as they doubtless do in the Empire well on the Hatchetigbee anticline in Washington County, Alabama, and in a number of wells in the peninsula of Florida, as pointed out by Bostick.²

STRUCTURE

The development of the ElDorado field has revealed a long narrow structure with an anticlinal axis extending in a slightly west of north and east of south direction paralleling a fault on the east which cuts off production abruptly to the east. Just east of the fault, and the associated salt water-bearing syncline, is a second structural high area, the outline of which has not been clearly defined. The development of this part of the field will doubtless show the influence of a secondary fold.

SOURCE OF OIL AND GAS

It is well known, to the student of the Coastal Plain formations of Louisiana and the other southern states, that the entire thickness of the Tertiary is lacking in bituminous shales. The Claiborne and Wilcox shales are generally found to be of a light grey to chocolate color. The latter is due to the presence of lignitiferous material. The Arkadelphia shales have more the appearance of oil-bearing shales than the Claiborne or the Wilcox shales but they can be discarded without argument as the source of any great amount of oil and gas. The only possible source of oil and gas in the Cretaceous is the Brownstown marl, and, in a few instances, as in the Elm Grove gas field, it is believed to be the source of the oil which

²Bostick, J. W., *Oil Weekly*, May 1920.

occurs in the so-called Blossom sand. But it is not conceivable, without further evidence and some distillation tests on this marl, that it can be the source of any great amount of hydrocarbons from the Nacatoch to the Glen Rose horizon.

The red shales which are believed to be of Lower Cretaceous age and which have been found to underly all of the producing fields of north Louisiana and south Arkansas, are even less likely to be the source of oil and gas than the Upper Cretaceous or the Tertiary. There is a lack of evidence by writers on Coastal Plain geology that oil and gas are indigenous to the sands in which they occur.

From whence then, has come the immense deposits of oil like that at Homer, Haynesville, Bull Bayou, Caddo, and ElDorado? All of the above mentioned fields, as well as Bethany, Elm Grove, Monroe, and the shallow Bossier fields are believed to be on separate buried hills which were doubtless in existence as such, previous to the subsidence and encroachment of the Cretaceous sea. Subsequent folding affected all Cretaceous and Tertiary sediments.

The deep synclinal trough which separates Homer from the Bossier field strengthens the belief that each field is a separate and distinct uplift with underlying hills of older rocks. The general trend of these buried hills roughly parallels the line of folding in the older rocks in south central Arkansas. The amount of uplift between the shallow Bossier field and the synclinal trough between there and Homer, as shown by the Nacatoch sand, is approximately 1700 feet.

Logs of wells drilled on these uplifts show a decided thinning of the Lower Cretaceous sediments. The existence of buried mountains and the thinning of the Cretaceous column leads easily to the inference that these old uplifts may contain Pennsylvanian shales or perhaps shales of older formations which are believed to be the source of the hydrocarbons in the north Louisiana and south Arkansas fields. Up to the present time no well in any of the producing fields has penetrated the older rocks so that it is not possible to ascertain the nature of these older formations. That these older shales do contain hydrocarbons is shown by the presence of asphalt in the Carboniferous rocks of Pike County, Arkansas,

and in Carboniferous and older rocks in eastern Oklahoma and near Mena, Ark.²

The Pre-Cretaceous rocks may have been fissured previous to the deposition of the Cretaceous and later sediments. In some of the fields as ElDorado, Homer, Bull Bayou, and Caddo later forces produced faulting which extended through the entire thickness of Cretaceous and Tertiary or it may be that the faulting has all taken place since the end of the Tertiary period. At any rate, these fissures extend downward to the source of the hydrocarbons.

As a general proposition the faulted structures produce oil, or gas and oil; the unfaulted structures produce gas only. The hydrocarbons no doubt have a common origin and are not indigenous to the sands in which they occur. In a faulted structure as at Homer, Bull Bayou, Caddo and ElDorado, the source of the oil is from some common source below where it is at present found. This is proven at Homer, where two sands 700 feet apart produce oil of the same gravity and quality. An open fault of more than 200 feet displacement through the center of the structure forms the avenue for the vertical migration of the oil. The vertical migration through faults and crevices is likewise accompanied by lateral migration into the sands or reservoirs in which the oil is found. The nature of the fissures and the extent of the lateral migration explains the various differences in the quality of the oils.

Gas will move more freely than oil in faulted structures and perhaps some of the gas in some structures has passed off through the fissures and been lost. In the unfaulted structures, as Elm Grove, and Monroe, gas has slowly penetrated the unconsolidated sediments of the Coastal Plains area from its origin. The more volatile hydrocarbons move upward through the rocks until they find a porous reservoir with a tight cap to hold them in place; when the reservoir has been filled the overflow passes upward until it is confined in another trap. Gas having traveled through the rocks would naturally leave behind its heavier constituents.

In the Elm Grove gas field the gas from the Woodbine sand, when the field was first opened, contained approximately 100

gallons of gasoline to the million cubic feet of gas. Gas from the Nacatoch sand in the same field, in its further migration, lost all of its gasoline content.

In the Monroe gas field there is a triple dome instead of a single dome. Here we find a somewhat different condition. The gas in the highest dome was devoid of gasoline content when the field was opened. The gas from the center dome contained about 100 gallons of gasoline to the million cubic feet of gas, while in the lowest or southeast dome the gasoline content was about 400 gallons to the million cubic feet of gas. Thus is seen the effect of lateral migration from one part of the structure to another.

Eldorado, like the north Louisiana fields, is located on an uplift which is a distinct unit and probably formed at the same time as the north Louisiana uplifts and separated from them by a deep synclinal trough not unlike those which separate the producing areas of north Louisiana.

The thinning of the geologic section and the corresponding nearness to the Pennsylvanian and older shales, together with the folding and faulting, have made possible the accumulation of oil and gas in the Eldorado Field.

K. C. HEALD: It is extremely important to obtain fossil evidence to establish the identity of the various oil-yielding sands in the fields of northern Louisiana and southern Arkansas. For instance it is possible, and in my own mind seems probable, that the red beds in the Eldorado field which Mr. Crider has assigned to the Lower Cretaceous are actually a part of the Bingen formation which is also red. If these red beds are in the Bingen, the encouragement to deep exploration is infinitely greater than if they are a part of the Lower Cretaceous.

EDWARD BLOESCH: The map of the Monroe, La., field as compiled by the U. S. Bureau of Mines shows faults occurring in the southeast part of the field, where the gas is richer in gasoline. I wish to ask Mr. Crider if his observations are different from the ones of the Bureau of Mines.

A. F. CRIDER: Since the report by the Bureau of Mines was published, a very important well has been drilled near the center of the NE $\frac{1}{4}$ of the NE $\frac{1}{4}$ of Section 34, T. 19 S., R. 5 E., by the Atlas Oil Company. The top of the Monroe gas sand in this well was found at a depth of 2142 feet below sea level. The well showed about 500,000 cubic feet of gas. The results of this well eliminates the possibility of a northeast southwest fault and shows a general plunging anticline the lowest part of which is to the southeast where we would expect the highest gasoline content in the gas.

STRATIGRAPHY OF A PART OF SOUTHERN UTAH

RAYMOND C. MOORE¹

INTRODUCTION

The occurrence of oil seepages and oil-saturated rocks in parts of southern Utah and the production of oil in small quantities in two southern Utah fields, one on San Juan River in the southeastern part of the state, the other near Virgin City in the southwestern corner of the state, has for some time attracted the attention of geologists and oil operators to the possibility of commercial production in this region. A further incentive has been the known existence of large anticlines and domal structures in east central and southern Utah and the probable existence of smaller structures of favorable character in which possible petroliferous formations are involved. The chief deterrent feature in the rapid exploration and testing of this country has been its inaccessibility and the very large cost of drilling. Exploratory work is, however, proceeding and will doubtless continue until the geological conditions and possibilities of oil production are fairly definitely known. Because of an intrinsic geologic interest which attaches to this classic region where early workers developed some of the fundamental concepts in geologic science, but particularly on account of its importance to the petroleum geologist who is concerned with the problems of this and adjoining regions, this brief summary of stratigraphic observations based on detailed and reconnaissance field work during the summer of 1921 is presented.²

The area examined by the writer lies in central southern Utah in Kane, Garfield and Wayne counties. Kane County borders the Arizona state line; each of the counties is bounded on the east by the deep, practically impassable canyon of Colorado River and extends westward from this stream a distance of some eighty to ninety miles. Studies in southern Utah were supplemented by reconnaissance examination on a trip south-

¹Published by permission of the Director, U. S. Geological Survey.

²The writer wishes to acknowledge valuable assistance by Messrs. A. C. Tester and P. C. Benedict.

ward from Kanab to the north brink of the Grand Canyon at Bright Angel Point.

Southern Utah is not reached by any railroad. Travel pro-

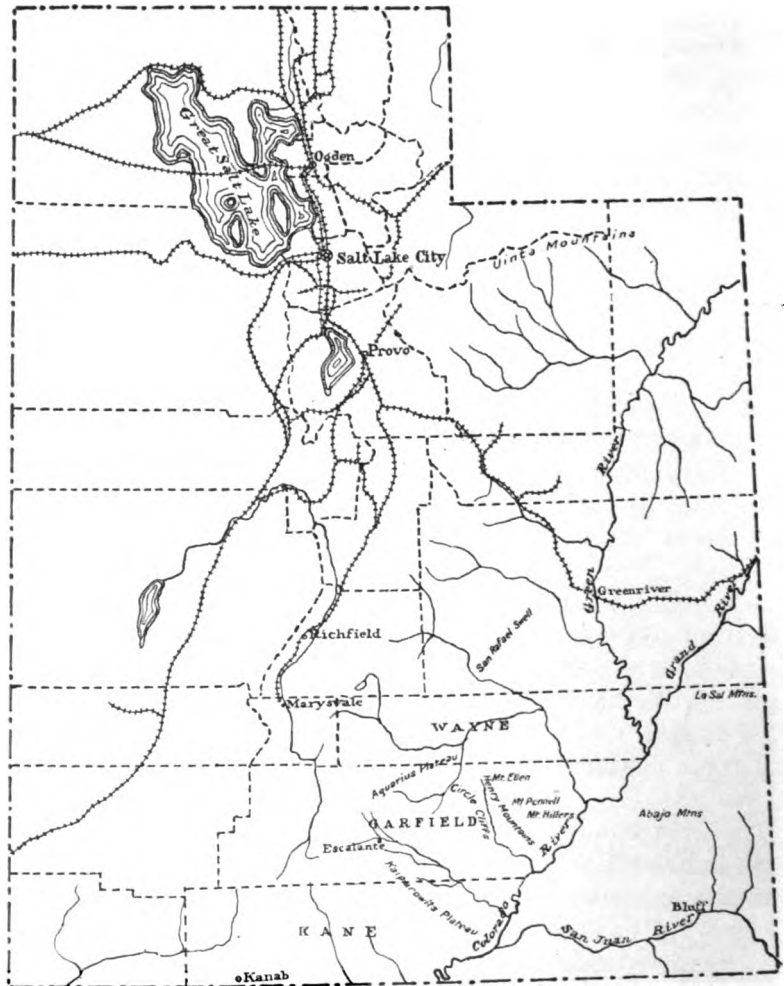


Fig. 1. Index Map of Utah.

ceeds by auto or wagon roads from the nearest convenient railway point to all settlements, some of them nearly 200 miles distant, but there is very much of the country which is not

reached by a road of any sort, where travel if possible at all must be by horse and pack-train. The rail-head of the central Utah Branch of the D. & R. G., at Marysvale is the point of

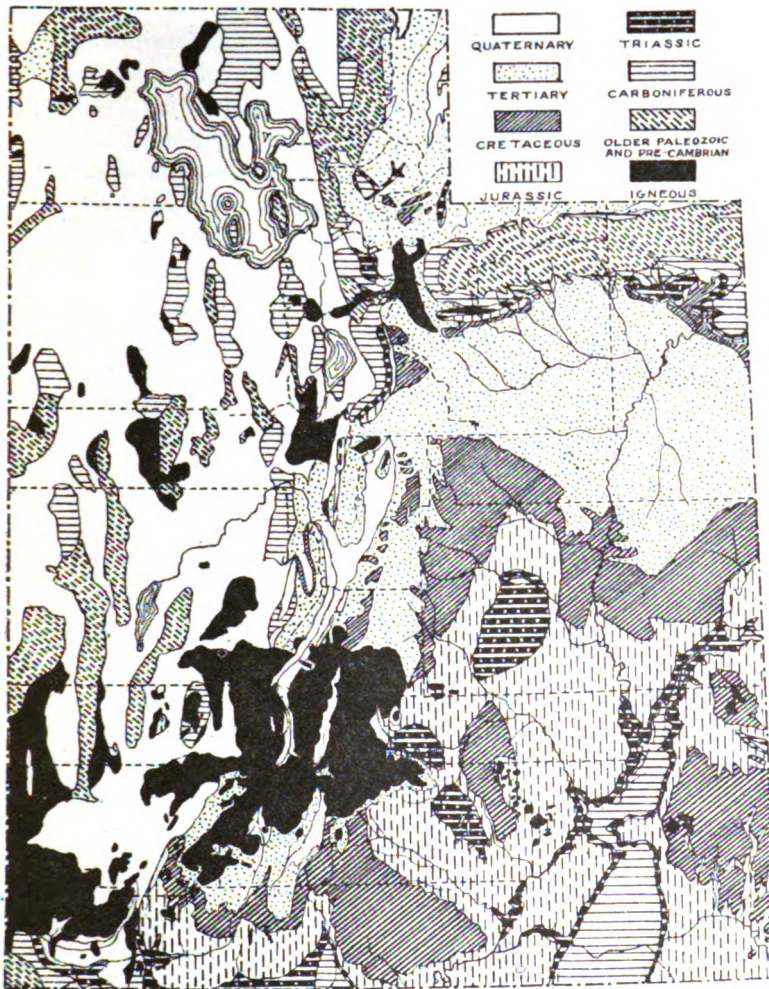


Fig. 2. Sketch geological map of Utah.

departure for Panguitch, Kanab and the western part of Kane, and Garfield counties. The eastern part of these two counties and all of Wayne County is more easily reached from Richfield or from Greenriver.

All of those striking features of desert or semi-desert plateau and canyon topography for which the Colorado Plateau region is famous are found in the portion of the province here under consideration—indeed, some of them are probably better developed in this district than anywhere else. The lofty, extensively lava-capped High Plateaus, much of whose surface stands more than 10,000 feet above the sea, here approach most nearly the deeply carved gorge of the great master stream of the southwest, the Colorado. Successive plateaus or great escarpments, each bounded by precipitous cliffs, lead like giant steps from the heights to the canyon depths. Erosion by running water has carved innumerable vertical-walled and impassable canyons. Laborious travel follows circuitous routes along the bottoms of these, mostly dry-floored canyons and across the shoulders of mountainous mesas. The southeasternmost of the High Plateaus is the Aquarius; a prominent south-projecting promontory almost cut off by erosion from the main body of the Aquarius is known as Table Cliff Plateau; farther west and extending southward into Kane County is Paunsagunt Plateau. The precipitous walls bounding these plateaus expose in many places the pink Tertiary formations of which they are composed and have come to be known as the Pink Cliffs. Southeastward from Table Cliff Plateau and nearly 3000 feet below it, Kaiparowits Plateau, upheld by strong Cretaceous sandstones, reaches some sixty miles, stopping short opposite Navajo Mountain at the canyon of the Colorado. The northeast face of the Kaiparowits is a high, nearly unbroken straight cliff and is appropriately designated the Straight Cliffs. The Escalante basin, an intricately dissected canyon area, lies below the Straight Cliffs, and beyond it to the northeast are the Circle Cliffs, a wall of nearly vertical cliffs which surround an elongate elliptical area trending northwest and southeast. On the east side of the Circle Cliffs are long, prominent hogback ridges formed by massive, uptilted sandstones which compose part of the Water Pocket fold. South of the Pink Cliffs in western Kane County are great south-facing cliffs, one composed of white sandstone, the White Cliffs, and another composed of red sandstone, the Vermilion Cliffs. In eastern Garfield County a variation in the characteristic topography is in-

troduced by several peaks composed of igneous rock, one of which rises to more than 11,400 feet. These, the Henry Mountains, are laccolithic in origin and the sedimentary rocks are upturned about them. The igneous rocks have been carved into alpine peaks, ridges and valleys, and in places there are great talus piles of angular rock fragments. The topographic features of southeastern Utah, extending northward to the San Rafael Swell, a feature closely resembling the Circle Cliffs, are shown in the sketch, Figure 3.

Colorado River, which is formed by the junction of the Grand and the Green at the east border of Wayne County, flows in an extremely irregular course southwestward, and to it all other streams in the region are tributary. The most important of these are, on the north, Fremont and Escalante rivers, and on the south, San Juan River, all perennial. Smaller streams, excepting only those of the high lands which are fed by melting snows and springs, are intermittent but at times of rain become muddy torrents. For the use of man, including the drilling of wells, dependence must be had on widely scattered small springs or seeps, and "tanks", naturally excavated hollows in sandstone or stream-bed in which rain water may accumulate. In drilling a test well in the Circle Cliffs it was necessary to haul all the water from 12 to 16 miles. Artificially constructed tanks may impound water if the local showers of the summer months chance to favor the locality selected. In the event of discovery of oil in commercial quantities in almost any part of southern Utah it would be possible to provide for water supply.

SEDIMENTARY ROCKS

The rock formations which appear at the surface in central southern Utah range in geologic age from Permian to Tertiary. In regions not far distant older rocks, Pennsylvanian to Pre-Cambrian, appear. A test well recently drilled by the Ohio Oil Company in the Circle Cliffs penetrated 3212 feet of Permian and older rocks. Description of these formations and discussion of their correlation may be divided into two parts, those which are exposed in the area under consideration, and those which do not here appear at the surface. The following tabu-

lar statement shows all of the stratigraphic divisions which are recognized:

Table of Formations

System	Formation	Description of strata	Thickness in feet
Tertiary	Wasatch	Limestone, calcareous sandstone, and shale, pink, white, and vari-colored, evenly stratified, rather soft. Outcrops in cliffs and forms slopes; composes the highest plateaus.	2000 +
	"Laramie" sandstone	Sandstone, yellowish gray, massive to medium bedded, with some sandy shale, a prominent cliff-forming division. Grades without break into formation below.	250-400
Cretaceous	Lewis shale	Shale, gray to drab, sandy containing some thin beds of yellow sandstone.	500 1200 +
	Mesaverde sandstone	Sandstone, yellow to brown, irregularly bedded, medium to massive. Contains lignite beds up to 4 feet in thickness. Forms prominent escarpment.	300-1000
	Mancos shale	Shale, bluish drab, argillaceous to sandy, very uniform in color and texture. Forms slopes and badlands. Thickness 1100-1200 feet.	2200
		Sandstone, yellowish, medium to massive, irregularly bedded. Forms mesas and hogbacks near Henry Mtns. Thickness 60-100 feet.	
		Shale, bluish drab, sandy, grading to fossiliferous sandstone at base. Shale contains abundant <i>Gryphaea newberryi</i> and other fossils. Thickness 900-1000 feet.	
	Dakota sandstone	Sandstone, yellowish to nearly white, in part conglomeratic, irregularly bedded, locally contains lignite.	6 100
	McElmo formation	Shale, maroon to light bluish gray, sandy, banded. Conglomerate and coarse gritty sandstone, maroon, yellow and gray, irregularly bedded. Forms escarpments and hogbacks.	197-565
Jurassic	"Upper Jurassic sandstone"	Sandstone and shale, thinbedded, maroon. Sandstone, very massive and very soft, generally white or light cream colored at top, middle and lower portions orange brown. Grades irregularly into very sandy, crossbedded shale. Weathers readily forming abundant dune sand.	973-1430
	"Gypsiferous zone"	Shale, pink to red, containing gypsum in beds up to 5 feet thick, and a few beds of white massive sandstone.	100-450?
		Shale, sandstone and siliceous limestone, dark maroon and light bluish green, forms distinct escarpment.	
	Navajo sandstone	Sandstone, light creamy yellow, white and pinkish, highly crossbedded, very massive, coarse grained, calcareous. Weathers in high cliffs, and in innumerable cones and towers.	1260-1400

System	Formation	Description of strata	Thickness in feet
Jurassic	Todilto formation	Sandstone, chiefly maroon, locally conglomeratic and coarse grained, thin- and extensively cross-bedded. Locally contains maroon sandy shale and thin, hard, bluish limestone.	125-215
	Wingate sandstone	Sandstone, mostly vermilion red to reddish brown, very massive, prominently jointed, outcropping commonly in a single vertical cliff resembling a palisade. Cross-bedded, but not prominently as in Navajo.	250-400
Triassic	Chinle formation	Shale and limestone, light bluish and lavender, the shale very calcareous and grading irregularly into hard, uneven, dense, mottled limestone. Locally near top a limestone conglomerate appears.	185-200
		Shale and sandstone, the shale varicolored, generally darker than division above but brilliant, sandy; the sandstone thin to massive, crossbedded. Contains much silicified wood appearing partly in great logs.	285-305
	Shinarump sandstone	Sandstone, light gray to yellowish, coarse grained to conglomeratic, very irregularly bedded and variable in thickness. Grades locally into bluish sandy shale. Contains silicified wood. Forms prominent bench.	10-125
	Moenkopi formation	Shale and sandstone, chocolate brown to yellowish, containing locally in upper portion very thin hard limestone beds. The shale very sandy and grading into shaly sandstone; the sandstone varying from thin-bedded, platy to thick, massive beds, in part saturated with petroleum.	304-480
Permian	Kaibab limestone	Limestone, white to yellowish, massive, more or less dolomitic, in part cherty, one widely distributed bed containing abundant angular fragments of chert. Lower part increasingly sandy and containing some beds of calcareous sandstone. Fossiliferous in part containing numerous brachiopods, bryozoans, etc.	125-165
	Coconino sandstone	Sandstone, white massive, saccharoidal, calcareous. Upper part exposed in canyons in central part of Circle Cliffs; penetrated by Ohio Oil Company well in Circle Cliffs but not differentiated from subjacent division.	
	Supai (?) formation	Sandstone, white to yellow, massive, containing some red material, a little shale and thin limestone. Penetrated by Ohio Oil Company well.	1630 (?)
Pennsylvanian	Goodridge (?) formation	Limestone, white, hard massive, with interbedded sandstone, white, gray and red, and some red shale. Penetrated by Ohio Oil Company well.	1552 (?)

ROCKS NOT EXPOSED

Information concerning the older rocks which in the portion of southern Utah under consideration do not appear at the surface is obtainable from the record of deep borings, and less



Fig. 3. Block diagram showing topographic features in a portion of southern Utah.

certainly from comparison with adjacent districts where these rocks are exposed. The only well which has penetrated the strata below the Kaibab limestone is that in the Circle Cliffs already mentioned, of which graphic record is shown in Plate II.

Older Paleozoic Rocks

It is possible that formations of Cambrian age underlie central southern Utah inasmuch as rocks belonging to this period

are extensively developed farther north in Utah, in the Grand Canyon region to the southwest and, less importantly, in southwestern Colorado. Ordovician and Silurian rocks are reported from northern and western Utah but do not occur in the Grand Canyon or in southwestern Colorado. Devonian limestone is found in the Grand Canyon section (up to 100 feet), in southwestern Colorado (Ouray limestone, 100-250 feet, partly Mississippian), and in northern Utah, and rocks of this age very possibly occur beneath central southern Utah. Older Paleozoic rocks have nowhere been recognized in borings in this region.

Carboniferous and Permian

The Mississippian appears to be very widely distributed in the west, being represented generally by very dense, massive, rather unfossiliferous limestones. In the Grand Canyon Mississippian fossils have been reported² from the lower part of the Redwall limestone which has a thickness of 600 to 700 feet in the canyon district, thickening to the west. In southwestern Colorado the upper part of the Ouray limestone, lithologically similar to the Redwall, contains Mississippian fossils. In central northern Utah and elsewhere to the north is a widely distributed massive, dense limestone ("Wasatch", Madison, etc.) in which sparse lower Carboniferous fossils have been obtained. It is possible, as suggested by Girty,³ that part of the lowermost beds exposed in the San Juan canyon at Goodridge may be Mississippian, though it is more probable that if rocks of this age are present they do not appear at the surface. Mississippian strata may be anticipated at depths beneath the surface in southern Utah.

Abundantly fossiliferous rocks of Pennsylvanian age (Goodridge formation) are known in the canyon of San Juan River west of Bluff (1350 feet exposed⁴) which are equivalent at least in large part to the Hermosa formation (1600-2000 feet) of southwestern Colorado. Corresponding beds appear at the surface in Cataract Canyon below the junction of the Grand

²Noble, L. F., The Shinumo Quadrangle, Grand Canyon district, Arizona. U. S. Geol. Survey, Bull. 549, 1914.

³Girty, G. H., in Woodruff's report on the Geology of the San Juan oil field. U. S. Geol. Survey, Bull. 471, 1912.

⁴Measurement by the writer.

and the Green. Pennsylvanian fossils are reported⁵ from the upper part of the Redwall limestone in the Grand Canyon region, and recently Reeside and Bassler⁶ have reported fossils identified by Girty as types belonging to Pennsylvanian or Permian which come from an horizon approximately 1000 feet below the top of the Redwall in southwestern Utah. These Pennsylvanian beds consist for the most part of alternating limestones, sandstones and minor amounts of shale. While it is uncertain how much of the Redwall is Mississippian and how much Pennsylvanian, and similarly how great thicknesses of these divisions may underlie central southern Utah, it is extremely probable that Carboniferous beds corresponding to these are present. The test in the Circle Cliffs encountered several hundred feet of limestones and sandstones, including some red rocks, in the lower part of the well. These strata in all probability represent the Carboniferous, but whether only a part of the Goodridge or all of the Goodridge and some lower beds is not known. The top of the Pennsylvanian is tentatively placed at the top of the limestone encountered at a depth of 1630 feet.

The Circle Cliffs well found white, yellow and brown sandstone with some red material and a little lime between the Kaibab limestone at the surface and the top of the limestone which may be considered as possibly Goodridge. This interval corresponds stratigraphically to that of the Coconino sandstone and Supai formation of the Grand Canyon section. Schuchert⁷ has pointed out the occurrence of an unconformity in the Supai beds of the Grand Canyon section which divides a predominantly shale zone above from a sandy one below. Noble⁸ proposes to introduce a new name (Hermit shale) for the beds above the unconformity and to restrict the name Supai to the beds below it.

Since the rocks below the Kaibab in the Circle Cliffs well

⁵Noble, L. F., loc. cit.

⁶Reeside, J. B., Jr., and Bassler, H., Stratigraphic sections from southwestern Utah, U. S. Geol. Survey, Prof. Paper, 129D, 1922.

⁷Schuchert, Chas., On the Carboniferous of the Grand Canyon of Arizona, Am. Jour. Sci., 4 ser., vol. 45, p. 356, 1918.

⁸Noble, L. F., Paleozoic formations of the Grand Canyon at Bass Trail, U. S. Geol. Survey, Prof. Paper, 131B (in press).

appear to consist mainly of sandstone it is not possible from evidence at hand to discriminate between the Coconino sandstone and the subjacent division, and because it is not known whether this lower division corresponds to the Supai as re-

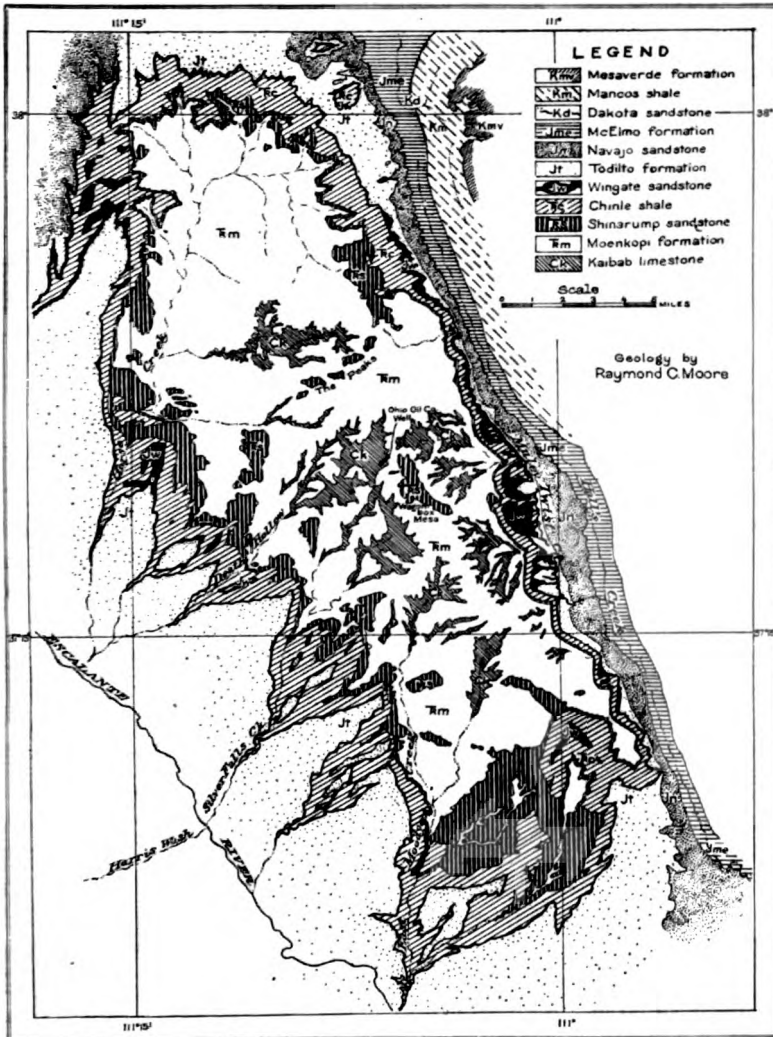


Fig. 4. Geological map of the Circle Cliffs, Garfield County, Utah. (Note: Upper Jurassic sandstone and shale, and gypsiferous zone included with McElmo formation).

stricted by Noble or to the other rocks as well, the strata below the Coconino may be designated as Supai(?).

ROCKS EXPOSED

Permian. The Kaibab limestone, with typical lithological and fossil characters, appears in the central part of the Circle Cliffs, its thickness ranging from about 125 to 160 feet. It consists of yellow to white, dolomitic, in part very cherty, and in part very sandy limestone, the subdivisions of which are fairly constant and easily recognizable in different exposures. It grades downward without sharp line of division into white, sugary sandstone which on account of lithologic resemblance and similar stratigraphic position may be identified as the Coconino sandstone. Outcrops of the Kaibab shown on the sketch geological map of the Circle Cliffs, Plate I, include undifferentiated Coconino. The upper surface of the Kaibab is uneven, and in places the upper members are missing. It is clear that erosion intervened before deposition of the Moenkopi. The Kaibab is referred to the Permian because examination of its fauna shows that while productids and other shells representing types common in the Pennsylvanian are present, elements which are distinctively Pennsylvanian are lacking; also because fossils which are identified as Permian have been found in the Grand Canyon region in strata below the Coconino⁹. The fauna of the Kaibab, determined from collections in the Grand Canyon region¹⁰ and southwestern Utah¹¹ contains a considerable number of species among which Girty¹² distinguishes two facies corresponding to different stratigraphic horizons: an upper, consisting chiefly of mollusks which represents the "Bellerophon limestone" of older geologists and a lower, the normal Kaibab fauna, characterized by a number of brachiopods, corresponding to the fauna which occurs in the San Andreas limestone of the Permian Manzano group in New Mexico. Fossils collected in the Circle Cliffs represent the normal Kaibab rather than the "Beller-

⁹Noble, L. F., loc. cit.

¹⁰Noble, L. F., The Shinumo quadrangle, Grand Canyon district, Arizona, U. S. Geol. Survey, Bull. 549, 1914.

¹¹Reeside, J. B., Jr., and Bassler, H., Stratigraphic sections in southwestern Utah, U. S. Geol. Survey, Prof. Paper 129D, 1922.

¹²Girty, G. H., in Reeside and Bassler, loc. cit.

ophon limestone" fauna. An earlier view which referred the Kaibab and underlying Coconino and Supai formations to the Pennsylvanian is now generally modified in the light of accumulating evidence to include the two upper and at least part of the lower in the Permian.

The Kaibab is not recognized in the San Rafael Swell¹³, in Cataract Canyon¹⁴, or in the San Juan oil field¹⁵, and it thus appears that the exposures in the Circle Cliffs represent the northeasternmost known extent of the normal type of this formation. The Kaibab is not to be correlated with the Goodridge formation of the San Juan oil field, as suggested by Gregory¹⁶, for the Goodridge has a very typical Pennsylvanian fauna with practically nothing, paleontologically, in common with the Kaibab, and it now appears that beds overlying the Goodridge are equivalent to the Coconino and Supai (?) which underlie the Kaibab. While the Kaibab cannot be traced northward or eastward it is widely distributed and is increasingly thick southwestward. In the Grand Canyon region it reaches a thickness of at least 600 feet¹⁷, and in southwestern Utah nearly 1000 feet.¹⁸ (See Plate I.) The Kaibab may be correlated with the San Andreas limestone in New Mexico and is probably equivalent at least in part to the fossiliferous Permian limestones (Park City) on the flanks of the Uinta Mountains, where the stratigraphic succession is almost identical with that of southern Utah and where is developed the "Bellerophon limestone" fauna recognized in the upper part of the Kaibab to the southwest.

Triassic. To the Triassic are referred three formations, the Moenkopi, Shinarump and Chinle. Excepting the Shinarump these are composed of non-resistant rocks which yield readily to weathering and erosion. They are also distinguished

¹³Emery, W. B., The Green River Desert section, Utah, Am. Jour. Sci., 4 ser., vol. 46, p. 555, 1918.

¹⁴Paige, Sidney, Personal communication.

¹⁵Woodruff, E. G., Geology of the San Juan oil field, Utah, U. S. Geol. Survey, Bull. 471, p. 76, 1912. Also personal observation.

¹⁶Gregory, H. E., Geology of the Navajo country, U. S. Geol. Survey, Prof. Paper 93, p. 22, 1917.

¹⁷Noble, L. F., loc. cit., pl. 9.

¹⁸Bassler, Harvey, and Reesi de, J. B., Jr., Oil prospects in Washington County, Utah, U. S. Geol. Survey, Bull. 726, p. 92, 1921.

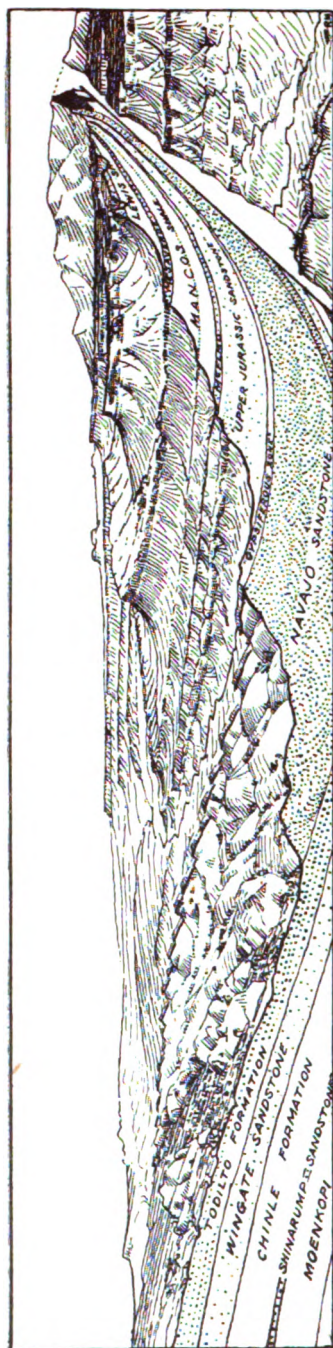


Fig. 5. Diagrammatic sketch showing Jurassic and Cretaceous formations west of the Henry Mountains. View looking east from top of Water Pockets fold toward Mt. Ellen, a laccolithic intrusion of igneous rock. A portion of the rocks have been removed to show the rock formations and structure.

by brilliant colors arranged in persistent alternating bands.

The Moenkopi consists almost entirely of sandstone and sandy shale, chocolate brown and yellow in color. The sandstones are in part hard and massive but are more generally thin-bedded to shaly and rather soft. The harder strata cap buttes and mesas or form projecting ledges; the softer beds weather in gentle slopes. The Moenkopi unconformably overlies the Kaibab and is unconformably succeeded by the Shinarump. Its thickness in the Circle Cliffs ranges from a trifle over 300 feet to nearly 500 feet, variations in thickness being mainly due to pre-Shinarump erosion. In places the irregularities at the top of the Moenkopi are very evident. A sandstone which ranges in thickness up to 50 feet and which is highly impregnated with oil occurs in the upper part of the Moenkopi. No fossils were found in the Moenkopi in the Circle Cliffs region but elsewhere numerous marine Lower Tri-

assic fossils have been found in it, which correspond to the *Meekoceras* beds of south-eastern Idaho.¹⁹

The Moenkopi formation is widely distributed in the Colorado Plateau region, in general thinning to the east and increasing in thickness to the west. In northeastern Utah the Moenkopi probably corresponds to fossil-bearing red beds containing the *Meekoceras* fauna, Woodside, Thaynes and Ankara²⁰. In the San Juan oil field Woodruff²¹ describes 1640 feet of red shales and sandstones overlying the Goodridge as Moenkopi (see Plate II); Gregory²² identifies only 500 feet here, excluding 845 feet of strata which were included by Woodruff; but Miser²³ in recent careful studies along the canyon of San Juan River has differentiated the beds above the Goodridge to include, in ascending order; Supai (?) formation, 380 feet; Coconino sandstone, 400-600 feet; Moenkopi formation 830-855 feet, including in middle portion De Chelly (?) sandstone, 0-90 feet; Shinarump; Chinle; Wingate etc. The sandstone identified as Coconino by Miser thickens to the northwest and north and appears to correspond to the very thick sandstone division which underlies the Kaibab in the Circle Cliffs, and the massive "Aubrey" sandstone in Cataract Canyon. The Moenkopi of the San Juan, as described by Miser is considerably thicker than in the Circle Cliffs, but farther southeast it is much thinner. In southwestern Colorado the Cutler formation may represent the Moenkopi. North of the Grand Canyon, in southwestern Utah²⁴ and south-

¹⁹Dr. G. H. Girty reports identifications of Moenkopi fossils from southwestern Utah and discusses the correlation of the fauna in Reeside and Bassler's paper on southwestern Utah. (U. S. Geol. Survey, Prof. Paper 129D). "There is scarcely room for reasonable doubt that Walcott's 'Permian' of the Kanab Canyon section, which is Moenkopi, is the same as the 'Permo-Carboniferous' of the Wasatch Mountains, and that the 'Permo-Carboniferous' of the Wasatch Mountains is the same as the well known Lower Triassic of Idaho."

²⁰Boutwell, J. M., *Geology and ore deposits of the Park City district, Utah*, U. S. Geol. Survey, Prof. Paper 77, 1912; see also Girty, G. H., *The fauna of the Phosphate beds of the Park City formation in Idaho, Wyoming and Utah*, U. S. Geol. Survey, Bull. 436, p. 8, 1910.

²¹Woodruff, E. G., loc. cit.

²²Gregory, H. E., loc. cit., p. 29.

²³Miser, H. D., Unpublished data.

²⁴Reeside and Bassler, loc. cit.

eastern Nevada²⁵ the Moenkopi is well developed, reaching a thickness of 2000 feet.

The Shinarump sandstone consists mainly of coarse, light colored sandstone which is locally conglomeratic and which grades in places to bluish sandy shale. It is extremely irregular in bedding and variable in thickness. The average thickness in the Circle Cliffs is about 50 feet, but measurements of less than 10 feet and of more than 125 feet are noted. The Shinarump sandstone is much more resistant than the adjoining formations and its outcrop forms prominent benches and small mesas (see geologic map. Fig. 4.) Fragments of silicified wood occur in this formation but are less common than to the south where the rock is coarser. Fossil plants were collected in the Circle Cliffs. Its fossils and stratigraphic relations indicate without question the Triassic age of the Shinarump. Within the Plateau province the persistent lithologic and associated stratigraphic features belonging to the Shinarump formation make it very widely and easily recognizable, but beyond the borders of the province it has not been identified.

The Chinle formation, which appears to grade normally upward from the Shinarump, is a relatively non-resistant division which outcrops in the slopes beneath the Wingate sandstone cliffs. It is commonly stripped for some distance back from the edge of the Shinarump escarpment below it. Two rather distinct members may be distinguished in the Circle Cliffs, a lower, consisting of dark, in part brilliantly colored sandy shales and irregularly bedded sandstones, and an upper, consisting mainly of hard, uneven, irregularly mottled light colored, dense limestone and calcareous shale. The lower division is commonly somewhat thicker than the upper, the total thickness of the formation in the Circle Cliffs ranging from 450 to 500 feet. The lower strata contain considerable petrified wood and in a few places large logs ranging up to 75 feet in length. Fossil invertebrates, not yet identified, were found also in the lower part of the formation. Else-

²⁵Longwell, C. R., *Geology of the Muddy Mountains, Nevada, with a section to the Grand Wash Cliffs in western Arizona*, Am. J. Sci., 4 ser. vol. 50, pp. 39-52, 1921.

where²⁶ remains of a number of Upper Triassic vertebrates have been discovered in the Chinle. Deposits equivalent to the Chinle or known by that name are very widely distributed in the Colorado Plateau region, and indeed, extend far beyond its borders. The thickness of the Chinle in the Circle Cliffs region is considerably less than to the southeast (San Juan oil field, 1332 feet; Navajo country, 1200 feet) or southwest (Washington County, Utah, 1000 feet; Muddy Mountains, southeastern Nevada²⁷, 800-3200 feet). In southwestern Colorado the Dolores formation which corresponds to the Chinle has a thickness of about 1000 feet in some places²⁸ but elsewhere is much thinner (Rico district, 400 feet, Ouray quadrangle, 100 feet) and locally disappears entirely²⁹, these variations being due to pre-La Plata erosion.

Jurassic. The Jurassic period is represented in southern Utah mainly by a series of great sandstones which in distinctive lithologic character and prominent topographic expression form one of the most striking elements in the make-up of the region. The combined average thickness of these sandstones is about 2000 feet. At least five subdivisions are readily distinguished in eastern Kane, Garfield and Wayne counties, some of which at least, are traceable over thousands of square miles in adjacent territory. In ascending order these subdivisions are: (1) Wingate sandstone, (2) Todilto formation, (3) Navajo sandstone, (4) "Gypsiferous zone," and (5) "Upper Jurassic sandstone." The lower three comprise the La Plata group as described in the Navajo country³⁰ the upper two were included by Lupton³¹ in the McElmo formation. No important stratigraphic breaks have been identified

²⁶Gregory, H. E., loc. cit., gives summary, pp. 46-7.

²⁷Longwell, C. R., The Muddy Mountain Overthrust in Nevada, Jour. Geol., vol. 30, p. 66, 1922.

²⁸Cross, Whitman, and Home, Ernest, Red Beds of southwestern Colorado and their correlation, Geol. Soc. Am., Bull., vol. 16, p. 473.

²⁹Personal observations, Rio Piedra, near Pagosa Springs, Colorado. See also, Cross, Whitman, and Larsen, E. S., Contributions to the stratigraphy of southwestern Colorado, U. S. Geol. Survey, Prof. Paper 90, p. 45, 1914.

³⁰Gregory, H. E., loc. cit.

³¹Lupton, C. T., Oil and gas near Green River, Grand County, Utah, U. S. Geol. Survey, Bull. 541, p. 124, 1914; Geology and coal resources of Castle Valley, Utah, U. S. Geol. Survey, Bull. 628, p. 23, 1916.

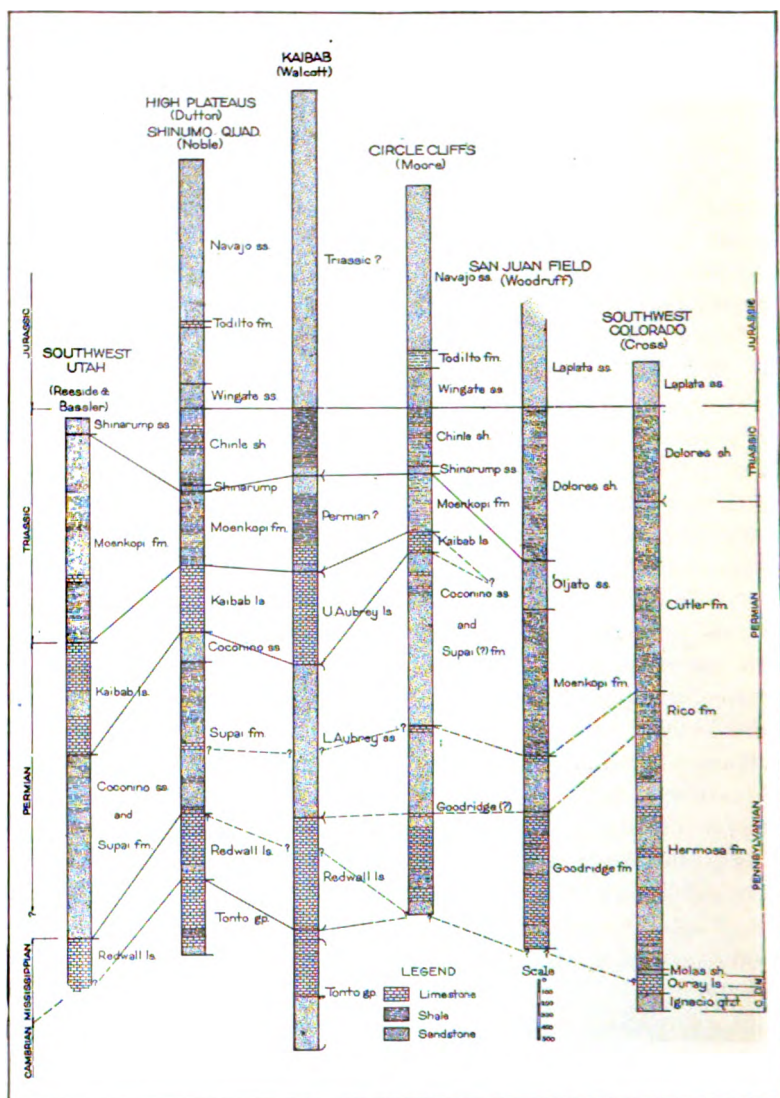


Plate I. Correlation of the Circle Cliffs section with adjoining regions.

within the Jurassic of southern Utah but it may be noted that while deposits of this age are chiefly non-marine, a portion contains a marine invertebrate fauna.

The Wingate sandstone is a resistant, very massive formation, for the most part brownish red in color, which outcrops as a single ledge with average thickness in the Circle Cliffs of about 300 feet. It is intersected by prominent joints which largely control weathering and produce the clean-cut palisade-like walls which characteristically mark the Wingate outcrop and which compose the cliffs of Circle Cliffs. Angular blocks of the sandstone strew the slopes of the Chinle. The Wingate is cross-bedded but because of uniformity of coloring and degree of cementation this feature is not prominent, as in the Navajo. Irregularities at the contact with the Chinle, the presence locally of conglomeratic strata at the base of the Wingate and of deep, sand-filled mud cracks at the summit of the Chinle³² indicate a break preceding the Wingate. There is no indication here of an important interval of erosion but as has been noted the pre-La Plata strata were at least locally deformed and beveled by erosion before deposition of the Jurassic sandstones. The Wingate is widely exposed in the Circle Cliffs (Fig. 4), in the Miners Mountain dome in Wayne County, in the San Rafael Swell and along portions of the canyons of Green, Grand and Colorado rivers in eastern Utah. As pointed out by Dake³³ the Wingate of Emery³⁴ in the San Rafael Swell includes in addition to the Wingate as described here, the Todilto and the Navajo. The Wingate comprises the lower part of the sandstones which form Comb Ridge east of the San Juan oil field; it is very extensively distributed in the Navajo country, northeastern Arizona, and in western New Mexico; it forms the Vermilion Cliffs in southern Kane County, Utah, and continues westward into Washington County, where, although retaining characteristic features, it cannot be differentiated precisely from the superjacent sandstone.

³²Gilbert, G. K., *Geology of the Henry Mountains*, U. S. Geol. and Geol. Survey of the Rocky Mtn. Region, p. 9, 1977.

³³Dake, C. L., *The horizon of the marine Jurassic in central Utah*, Jour. Geol. vol. 27, 1920.

³⁴Emery, W. B., loc. cit.

The Todilto formation consists of thin and irregularly cross-bedded sandstone, conglomerate, sandy shale and locally in minor amount, of dense, blue limestone. The color is commonly dark red or maroon. The average thickness of the formation in the Circle Cliffs is about 175 feet. Striking contrast in physical characters, especially bedding, color and composition, and prominent topographic expression, makes very easy the differentiation of the Todilto formation. It was traced without finding essential change through eastern Kane, Garfield and Wayne counties; it was observed at many points in the canyons of Colorado and San Juan rivers³⁵; and it is widely distributed in the Navajo country. The Todilto is perhaps represented by a thin-bedded, calcareous division noted by Cross³⁶ in the La Plata sandstone of southwestern Colorado, but southwest of the Circle Cliffs it gradually becomes indistinct.

The Navajo sandstone, largest single division of the Jurassic in southern Utah, is a thick, remarkably cross-bedded, massive formation of uniform character which is very widely distributed in the Colorado Plateau province. It is light-colored, mostly white to light creamy yellow but in places contains parts which are light orange red. The sand is rather loosely cemented. Weathering commonly etches the cross-bedding so that, aided in places by differences in coloring, it is very prominent; erosion, partly controlled by cross-bedding, develops forms which may be associated with the Navajo as characteristic, rounded domes, mosque-like towers, wigwams and irregular shapes. Caves and in places great natural bridges appear. In the Glen Canyon of Colorado River and in the White Cliffs of western Kane County, the Navajo outcrops in sheer, nearly vertical cliffs several hundreds of feet high. The thickness of the Navajo in eastern Garfield County is about 1300 feet; toward southwestern Utah it increases somewhat.

The Navajo is succeeded by red and light blue sandy shale, hard, evenly bedded siliceous limestone, sandstone and gyp-

³⁵Longwell, C. R., Miser, H. D. and Paige, Sidney, Unpublished data.

³⁶Cross, Whitman, Geology of the Rico quadrangle, U. S. Geol. Survey, Geol. atlas, folio 130, p. 5, 1905.

sum. Change in lithologic character is very marked but there is no certain evidence of unconformity. The strata of this zone have not been separately distinguished stratigraphically and may, pending further field studies, be designated conveniently as the "Gypsiferous zone." In this there are two subdivisions, somewhat different lithologically and distinctly expressed topographically. The lower of these is probably equivalent to the fossiliferous marine Jurassic described by Lupton³⁷ and Dake³⁸ a short distance farther north. The average thickness of this zone in Garfield County is 100 feet. The division was correlated with the Todilto by Emery³⁹ and was by Lupton⁴⁰ included in the McElmo formation. With the succeeding sandstone division this "Gypsiferous zone" is here tentatively excluded from the McElmo, which is a fresh water formation apparently equivalent to the Morrison formation of Cretaceous (?) age.

Massive, soft, cross-bedded, orange-brown sandstone, grading in places at the top to light creamy yellow or white, and changing somewhat irregularly in parts to sandy shale, is here designated as "Upper Jurassic sandstone." This soft sandstone division has a thickness of 975 to 1430 feet in the Water Pockets fold and northeast of Kaiparowits Plateau but it is largely concealed on account of the readiness with which it yields to the attack of weathering agencies. It follows the "Gypsiferous zone" without break and is designated as Jurassic only on the basis of its association with this horizon of known Jurassic age and its position below the McElmo which appears to overlie it unconformably. This sandstone was erroneously called Navajo by Emery⁴¹.

Cretaceous (?) The McElmo formation is here distinguished to include 200 to 600 feet of irregularly-bedded conglomerate, coarse grit, sandstone and banded sandy shale, red, maroon, light bluish and yellow-brown in color. The conglomerates occur at the base of the division and range in

³⁷Lupton, C. T. Geology and coal resources of Castle Valley, Utah, U. S. Geol. Survey, Bull. 628, p. 24, 1916.

³⁸Dake, C. L., loc. cit.

³⁹Emery, W. B., loc. cit.

⁴⁰Lupton, C. T., loc. cit.

⁴¹Emery, W. B., loc. cit.

thickness up to 150 feet. In places they contain fragments of silicified wood and reptile bones. The occurrence of the conglomerate and unevenness in the surface on which it rests indicate an erosion break. Deposits corresponding to those here indicated are widely distributed in parts of the Plateau province but have not been studied in detail.

Cretaceous. The Cretaceous is represented in southern Utah by exposures in the vicinity of Henry Mountains, along the southern border of the High Plateaus in western Garfield and Kane counties, and in a southeastward projection of which Kaiparowits Plateau is the chief part, extending into eastern Kane County. The total thickness of the Cretaceous section is about 3500 feet. The rocks consist of alternating divisions of rather somber colored bluish drab shale and light yellowish brown sandstone, the former appearing in gully-scored slopes and badlands, and the latter in cliff-margined escarpments and hogbacks.

The lowest division, the Dakota sandstone, consists of light colored sandstone, conglomerate and sandy shale, and contains in places thin beds of lignite. It has a maximum thickness of a little more than 100 feet along the front of Kaiparowits Plateau where it forms a prominent bench, but along the Water Pockets fold west of the Henry Mountains it is much thinner, and in places is wanting. The Dakota appears unconformably to overlies the McElmo.

The Mancos shale consists mainly of bluish drab, argillaceous and in part sandy shale, containing in its middle portion a thin but rather persistent sandstone (Tununk sandstone member) 50 to 100 feet thick. The shale below this sandstone is 900 to 1000 feet thick, fossiliferous, contains great numbers of *Gryphaea newberryi* and other forms, and grades at the base into extremely fossiliferous brown sandstone. The shale above the middle sandstone is uniformly colored and textured shale which has a thickness of 1100 to 1200 feet. The total thickness of the Mancos in the vicinity of the Henry Mountains is about 2200 feet. In the face of Kaiparowits Plateau and southwest of Table Cliff Plateau the fossiliferous lower shale and basal sandstone are identical with exposures near the Henry Mountains, but in the latter

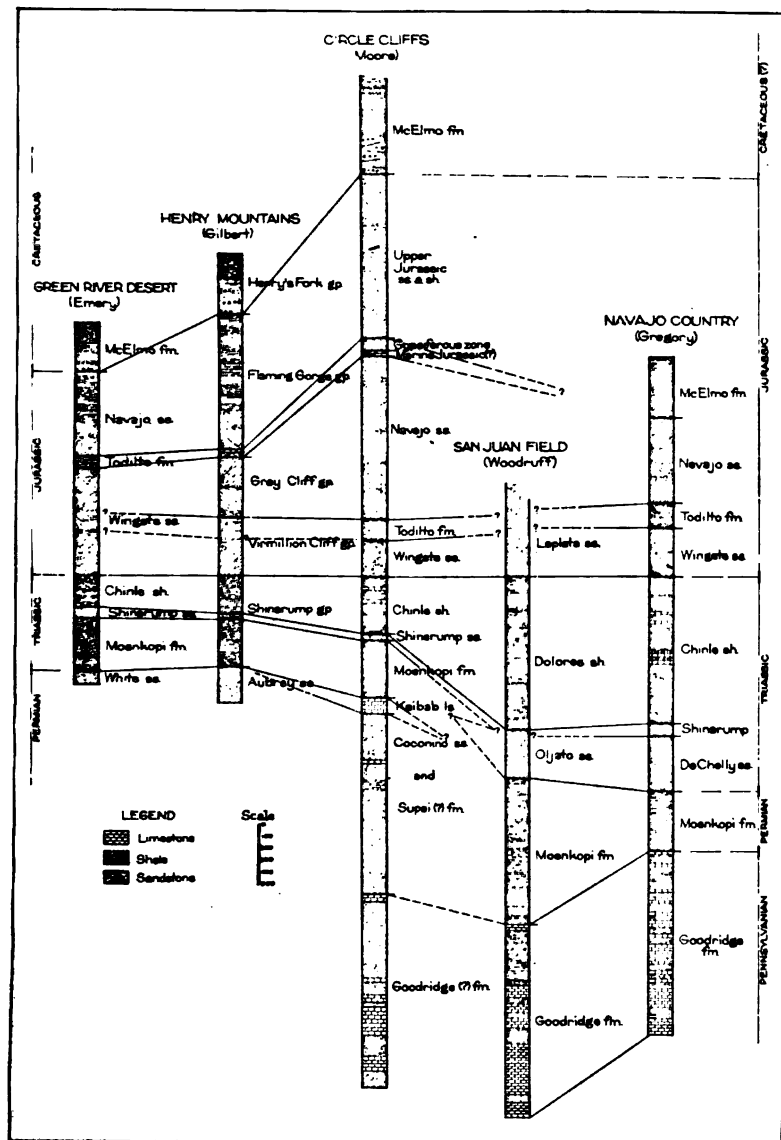


Plate II. Correlation of the Circle Cliff section with adjoining regions.

area no sandstone corresponding to the Tununk member is found. Near Table Cliff a measurement of 2100 feet of Mancos was obtained.

The Mancos shale is overlain with apparent conformity by irregularly bedded, massive, yellowish brown sandstone which in the vicinity of the Henry Mountains contains lignite in beds up to 4 feet thick. The thickness of this sandstone (Blue Gate sandstone of Gilbert⁴²) is 300 to 400 feet near the Henry Mountains but in Kaiparowits Plateau and near Table Cliff Plateau its thickness increases to about 1000 feet. No fossils were obtained from the sandstone but, as noted by Lee⁴³, comparison with the Cretaceous sections of adjoining regions indicates that this formation is probably Mesaverde. It is extremely improbable that this sandstone could represent the Ferron sandstone of Castle Valley, some 50 miles to the north, as intimated by Lupton⁴⁴. The Ferron occurs about 600 feet above the base of the Mancos and is overlain by 3000 feet of Mancos shale, while this sandstone is found 2200 feet above the base of the Mancos and, as seen in the Henry Mountains is succeeded by only a few hundred feet of shale.

The sandstone here designated as Mesaverde is overlain by sandy drab shale, somewhat lighter in color than the lower shales and having a brownish cast. Near the Henry Mountains this shale is 500 to 700 feet thick and contains in its upper part thin beds and lenses of sandstone. South of Table Cliff Plateau the thickness of this division is more than 1000 feet but measurement was not obtained. Based on comparison with the Cretaceous sections to the east this shale may be identified as the Lewis.

The Lewis shale, thus designating the division just described, is overlain conformably by massive yellowish gray sandstone which east of the Circle Cliffs appears in a prominent tableland bounded by high sheer cliffs. Its thickness is about 300 feet according to measurements made at its west

⁴²Gilbert, G. K., loc. cit., p. 4.

⁴³Lee, W. T., Relation of the Cretaceous formations to the Rocky Mountains in Colorado and New Mexico, U. S. Geol. Survey, Prof. Paper 95, p. 50, 1915.

⁴⁴Lupton, C. T., loc. cit., p. 32.

margin but Gilbert⁴⁵ reports a thickness of 500 feet. This sandstone (Masuk sandstone of Gilbert) probably represents the "Laramie" of southwestern Colorado which is apparently of Montana age⁴⁶.

Tertiary. In the Aquarius, Table Cliff, Paunsagunt and other of the High Plateaus may be found exposures of the youngest stratified rocks of the region, pink, lavender, white and vari-colored limestones, sandstones and sandy shales of Eocene age. These rocks, which in Garfield and Kane counties have been referred to the Wasatch, appear in vertical cliffs and in fantastically carved, brilliantly tinted walls of canyons heading at the margin of the plateaus, such as the famous Bryce Canyon west of Tropic. The thickness of the Tertiary in this region is about 2000 feet. Much of it, especially to the north, is buried beneath a great accumulation of extrusive igneous rocks.

The Tertiary rests with profound unconformity on the subjacent rocks. Along the margin of Table Cliff Plateau appear at different places next beneath the Tertiary, "Laramie sandstone" (?), Lewis shale and Mesaverde sandstone. Eastward along the edge of Aquarius Plateau the Tertiary is successively in contact with the Mancos shale, Dakota sandstone, McElmo formation, "Upper Jurassic sandstone," "Gypsiferous zone" and finally the Navajo sandstone. An important deformative movement, regional in character, which produced such structural features as the Water Pocket fold and the Circle Cliffs dome, occurred following Cretaceous deposition. Before sedimentation in early Eocene time this deformed rock series had been planed off by erosion to a nearly level surface, a denudation involving the removal in places of rock strata some thousands of feet in thickness.

DISCUSSION

E. G. WOODRUFF: Mr. Moore's paper presents such excellent geological data which must have been obtained only through physical hardship in this most difficult region that I do not presume to discuss it in detail. However, as he has not especially discussed petroleum possibilities a brief memorandum on that subject may be added. Several years ago a

⁴⁵Gilbert, G. K., loc. cit., p. 4.

⁴⁶See W. T. Lee, loc. cit. p. 48.

number of wells were drilled near Goodridge, at one time a post-office, on San Juan River, Utah. These wells were small, the best one yielding not over 50 barrels initial production. Also they were shallow, being less than 300 feet deep. Structurally these wells are in a syncline. This structure is small but very well defined. It seems probable that the unusual position of the oil in the structure is explained by the aridity of the climate and by the deep trenching of the strata by the canyon of the San Juan River. The rainfall is meager and of the torrential type when it does come, so that the percent of run-off is great and the proportion of water that goes into the ground small. Also the deep canyons offer opportunity for any water above the level of the canyon floors to escape. Therefore the strata are dry. There is no water to lift the oil into the anticlines and it rests in the synclines. It simply obeys the laws on which the anticlinal theory is based.

JOHN L. RICH: About two years ago it was my privilege to trace certain of the formations described by Doctor Moore across New Mexico. Mr. Hager says he has traced the Coconino sandstone from the Grand Canyon across Arizona to the Fort Defiance uplift. Farther east, at the east end of the Zuni Mountains, is a series of red shales and sandstones resembling the Supai formation, overlain by typical Coconino sandstone, and that in turn by a limestone, evidently the Kaibab. Farther east in the Socorro district, is the same series of rocks, having the same general characteristics of sequence, color and composition, but there called the Manzano group with the Abo-Yeso red beds at the base, correlating with the Supai formation, a massive unnamed sandstone above, the equivalent of the Coconino, and the San Andreas limestone at the top, corresponding with the Kaibab. Farther east the same formations may be traced into Guadalupe County and the massive sandstone beneath the San Andreas is found to be the same as the Glorieta sandstone, which caps Glorieta Mesa. Thus the Supai, Coconino and Kaibab formations of the Grand Canyon may be traced eastward to east central New Mexico where they correspond to the Abo-Yeso, Glorieta and San Andreas formations of the Manzano group.

MAX W. BALL: I have been asked by some of my neighbors in which of the formations so clearly described by Dr. Moore oil is found. Production in Utah, although in small quantity, has been found at two horizons, the Goodridge and the Moenkopi. In the San Juan field of southern Utah, between 30 and 50 miles west of the town of Bluff, a number of wells have produced oil from sands in the Goodridge formation of the Pennsylvanian. These wells have never been profitable, but they have produced oil in quantities that would have been commercial if the wells had been more favorably located with respect to transportation and market.

In a small area on the Rio Virgin in the extreme southwestern part of

Utah, a few wells have been drilled into the Moenkopi and have produced small quantities of oil. Production is said to have reached 10 barrels per day, and these small quantities have been sufficient to warrant production for a small local market.

In my opinion, and in that of a number of other geologists who have studied Utah carefully, the Moenkopi is the most promising of the pre-Tertiary horizons. Although this formation contains comparatively little organic shale or bituminous limestone, the out-crops are oil saturated with a persistency that is astonishing. Along the Orange Cliffs on the west side of the Green River, and "Under the Ledge" along the Dirty Devil River, there are numerous oil seeps; some of which drip oil sufficient to fill a tin cup in a comparatively short time. Around the great uplifts of the San Rafael Swell and the Waterpocket flexure the Moenkopi shows evidences of oil in perhaps three out of every four canyons. In some of the exposures which do not appear to contain oil chloroform tests show the presence of oil in considerable amounts. I have been told that similar evidences of oil are present around the Circle Cliffs uplift.

Farther to the south, between the Colorado River and the Rio Virgin, the Moenkopi is very thin and gives practically no evidence of oil, and on the east side of the Green River, near Moab, the Moenkopi is for the most part unpromising. I am told that farther east oil is found at places on the east side of the LaSal Mountains in western Colorado.

The oil possibilities of the Moenkopi have not been tested by drilling through the formation on a favorable structure. The wells on the Rio Virgin are on anticlinal noses; the wells that have attracted much recent attention to Utah, those on Circle Cliff and San Rafael Swell, were started below the Moenkopi; that at Huntington was started too high in the Cretaceous to reach the Moenkopi; the tests at Duchesne and Hill Creek start in the Tertiary. A well is now being drilled by the Ohio Oil Company on the Cainville structure, a rather favorable dome which will test the Moenkopi at from 3,000 to 3,700 feet, and a well is now being drilled by the Utah Oil and Refining Company on the Farnham anticline, a closed structure, which should penetrate the Moenkopi at approximately the same depth.

A number of other more or less favorable structures are known under which the Moenkopi is within drilling depth. Among these may be mentioned the Woodside structure, a fairly large and well closed anticline, probably the most promising Moenkopi structure in Utah, lying off the northeast end of the San Rafael Swell; the Last Chance structure, lying southwest of the San Rafael Swell and northwest of the Waterpocket flexure, a gradual but definitely closed anticline cut by a small basalt dike; and the Desolation structure, a well defined and well closed dome, cut by numerous basalt dikes. The Leonard Petroleum Company is drilling a well on the Salt Wash structure, a relatively small and none too clearly closed structure underlain by the Moenkopi.

Thus the Meonkopi lies within drilling depth on at least five favorable structures, of which two are being tested. The Goodridge sand, judging from observations in the Colorado River canyon and elsewhere, is probably of importance in only a small part of southeastern Utah, although it and related sands may be of importance in parts of southwestern Colorado.

C. W. TOMLINSON: The section exposed on the San Rafael Swell, about 100 miles north of the Circle Cliffs area, is very similar to that shown by Doctor Moore in the Circle Cliffs. Further, the strata here correlated with the Kaibab show striking similarities to part of the Park City formation of northern Utah, which in turn is correlated with the Embar of Wyoming. Also the Coconino or Aubrey sandstone of the San Rafael Swell can be correlated with much confidence with the Weber quartzite of northern Utah, and thence with the Tensleep of Wyoming. The Morgan red beds of northern Utah then match with the Amsden of Wyoming and part at least with the Supai of southern Utah and Arizona. The Redwall surely includes a representative of some of the Carboniferous limestones of northern Utah and Wyoming. Thus the major stratigraphic units of the Carboniferous occur in constant sequence from southern Montana through Wyoming and Utah into Arizona and New Mexico.

CHARLES SCHUCHERT: I had not intended to say anything about Professor Moore's correlation, but after two speakers have endorsed "long-range correlations on the basis of similar rock characters" I think it advisable to ask the workers for more fossil evidence. Long-range correlations on the basis of lithology will not do.

The stratigraphic sequence of the Colorado Plateau has been hurriedly worked over by many geologists during the past sixty years, and an analysis of their correlations shows that while each and every worker has added more or less to the sum of our knowledge, yet there is even today no complete agreement. The region is a most difficult one in which to make out the sequence, because of the several unfossiliferous sandstones and the rapid transition of the limestones into shales and sandstones. Finally, the source of the sandstones and shales was varied, for high lands existed not only to the north and in eastern New Mexico, but even more so in northwestern Mexico.

Not only should these things make for caution, but the further fact that the fossils do not always tell the correct geologic age, since some "Permian" fossils (those of the Kanab) are now known to be of early Triassic age.

A few years ago the speaker visited the Grand Canyon at Bright Angel, and found the Coconino sandstone, of Permian age, resting disconformably upon the Upper Supai red beds (290 feet thick), also of Permian age according to the plant evidence collected by him and identified by David White. Below the occurrence of these plants there is a

marked erosional unconformity, followed by the Lower Supai (900 feet thick) of similar red beds, all of which appear to be representative of but a small part of Pennsylvanian time. Some of the uppermost Red-wall limestones in the region of Bright Angel may be Pennsylvanian in age, but the greater part are clearly of Lower Mississippian (Madison) time. This stratigraphy has been described in the *American Journal of Science* for May 1918, pp. 347-361.

RAYMOND C. MOORE: With Professor Schuchert's remarks concerning the difficulty of precise and definite correlation of an unfossiliferous rock series which exhibit somewhat varying lithologic characters in different regions I am entirely in accord. However, such remarks can hardly apply to more than a portion of the stratigraphic section of the plateau province, for one of the most striking of all the remarkable features in the geology of this region is the surprising uniformity in lithologic character of some of the stratigraphic formations, permitting confident recognition over thousands of square miles of various key horizons which are at least homotaxially equivalent. It enables five Survey geologists working independently in different parts of the plateau country in southern Utah and northern Arizona during the last field season to compare in detail the stratigraphic observations made, to identify corresponding units throughout the region, and to recognize equivalent units described by other workers. Field work has traced some of the formations continuously for hundreds of miles and I believe there can be no reasonable question concerning the equivalences of the majority of the Circle Cliffs formations and those of exposures even at long distances in certain directions.

Concerning the Coconino-Supai portion of the section, to which Professor Schuchert particularly refers, and, it might be added, concerning a number of features in the Moenkopi, there are questions which can be settled, if at all, only after detailed field work in which the formations are followed practically without break throughout the region. For example, while identical stratigraphic position, relation to adjoining formations, lithologic character and numerous fossils allows no uncertainty as to the equivalence of the limestone identified as Kaibab in eastern Garfield County Utah, with some part at least of the Kaibab limestone of the Grand Canyon country, the relations of the sedimentary rocks beneath the Kaibab in these two regions are quite uncertain.

ROCK DISTORTION ON LOCAL STRUCTURES IN THE OIL FIELDS OF OKLAHOMA

JAMES H. GARDNER

By distortion is meant the state, condition or effect of being malformed or twisted out of shape. In this case, distortion refers to sedimentary strata associated with local small sharp folds at rather remote distances from areas of major deformation. Is it not remarkable that the local bending of the earth's stratified rocks has progressed with such great regularity that the individual layers of rock are, as a rule, so little distorted or changed from their original state? Tremendous forces have been necessary to lift and fold so great a thickness of sedimentary rocks as the whole of the Paleozoic system; yet, there is abundant evidence that in the oil fields of Oklahoma all of the series which are here represented in this great system are folded on each individual structure all the way from the surface down to the pre-Cambrian complex, which in all probability is itself correspondingly folded. At the time of deformation several thousand feet of sandstone, limestone and shale strata were involved. From the original deposition of stratum on stratum which was laid down for the most part in fairly uniform continuity and regularity of bedding, we now find monocline, terrace, syncline, dome and their various modifications all reasonably near to some area where geodynamic forces have culminated in an area of diastrophic movement.

All of these structures, including the range of crystalline mountains, the geanticline or "uplift" and the local folds of the oil fields, are areas of rock failure or incompetency; using in this sense, the terms of Leith, Chamberlin and Willis. The combined strength of the strata has been overcome in each area of folding, both regional and local. Whether the forces were applied laterally or in a large measure vertically, is a matter which will be discussed and on which the matter of epiclinal distortion has a bearing, and on which we are gaining new light. All are agreed that the strata have been deformed

at considerable periods of time after their deposition and at great depths below the surface where the load of overlying beds was very great. Formations which now lie at the surface, were deeply buried at the time of folding. A long period of subsequent erosion and removal of sediment has taken place since the period of deformation, so that we are now enabled to see along the outcrop stratified rocks which carried a great load and on which there was exerted a tremendous pressure when they were folding.

Notwithstanding all this, the strata have been lifted and flexed with an impressive regularity. Parallel beds of rock of nearly uniform thickness have been bent and arched in many cases without notable disturbance of their primary form. Each bed has preserved rather uniform thickness without undergoing disruption of its individual rock structure. However, it is just the exceptions to this rule to which the writer is here calling attention. It is his observation that in many cases strata lying now at the surface on local folds, particularly on the axes or flanks of domes, anticlines and synclines show plainly that they have not preserved their original form; that their strength has failed against the forces of folding and that as a result they are distorted.

The matter of local distortion on folds has a commercial or economic application, in that it is one of the distinguishing features of flexure and may lead to the discovery of a good structure or to further evidence of folding in areas where exposures are meager. Taken in consideration with other corroborative evidence, it has a scientific application with reference to the nature and origin of the forces that caused the deformation. The writer is not aware that this feature of structural geology in the oil fields has been previously discussed in public, except in his recent oral reference to the same before a meeting of the Tulsa Section of the American Institute of Mining and Metallurgical Engineers.

Geologists generally have not observed closely the evidences of distortion, but have been inclined to believe that all irregularities in an individual rock stratum are only cross-bedding or were caused by other factors connected with original deposition. However, the responses from a number of geologists

PLATE I.



Fig. 1. Distorted sandstone (Pennsylvanian) on east flank of structural dome Sec. 26, T. 23 N., R. 7 E., Osage County, Oklahoma. Note that bedding plane C-D shows an offset at point E where it is intersected by distortion plane A-B; the latter ends at point E and is clearly of later origin than time of deposition. To the left bedding plane C-D is cut off by distortion plane J-K.



Fig. 2. A further example of distorted sandstone (Pennsylvanian) in a detached fragment showing parallel bedding planes squeezed out of original form. Sec. 26, T. 23 N. R. 7 E. Osage County, Oklahoma.

have been favorable in substantiating the fact that local distortion does exist, even in connection with local folding of the low degree of intensity and comparative mildness that characterizes the oil fields of the Mid-Continent region.

Let us diverge from the petroleum industry for a moment and recall some of the structural features of the sedimentary rocks as shown in the coal fields. Coal mining permits underground observation of the effect of structural movement on stratified rock. Coal is mined in rocks which have undergone various degrees of movement, from the normal, nearly level bituminous beds of the interior basins to the closely crumpled and faulted strata of the anthracite fields. In coal-mining, we meet with the terms "mashing" and "squeezing" in connection with areas of local and comparatively mild disturbance. Frequently a coal bed squeezes out at a particular point, and an abnormal thickness of coal lies adjacent to the "squeeze-out," showing a mashing, crawling or deformation of the bed from its original natural thickness. This necessarily results in a change in the structural composition of the coal. So it is in the oil fields. Beds of shale frequently "mash" or "squeeze" to abnormal thickness or thinness on the local structures. Two columnar logs of nearby wells may correlate at the top of the logs and also at the bottom of the logs, whereas one of the logs will show a greater thickness of material in the central portion than the other, so that one log must be crumpled or shortened in comparison with the other in order to adjoin consistently the tops and bottoms of the two adjacent logs. This condition can readily be explained by the theory of "squeezing" or "mashing" of the clay-shale beds involved in the section. The sudden inconsistent deepening of an oil sand, or rise of an oil sand, as compared with closely adjoining logs, where not indicated in the shallower beds, generally can be explained satisfactorily only on the theory of a "squeeze" or distortion of the overlying beds of shale. Furthermore, it is possible that an oil sand itself, in some instances, has been "squeezed" out, or suddenly "thickens" or "thins," from adjustment to the forces that produced the local folds.

What would be the effect of rather pronounced local fold-

ing on a very soft, unconsolidated sandstone deeply buried and consequently carrying a heavy load? This query refers to a loose incoherent sand that would permit of the creeping or crawling of the sand grains to spots of least resistance. Does the theory of distortion or adjustment to the forces of folding in such a case seem unreasonable? The sudden thickening or thinning of oil sands on structure may not always be due entirely to the factors of deposition. Some of their inconsistency in thickness and porosity may be due to their having been subjected to strong dynamic forces.

The writer has observed distortion in beds of sandstone, shale and limestone, as illustrated in part by the accompanying photographs. In the case of shale, distortion is usually in the form of local "squeezing" or sudden changes of thickness accompanied by an irregularity of the bedding planes. In this connection, however, the observer should be careful and not confuse distortion with exfoliation due to weathering or to concretionary growths in the shale mass, if he is basing his observations on surface exposures. In the case of limestone, distortion is least observable,—due, perhaps to the competency or resisting ability of such rock,—but in the case of sandstone, it commonly is evident. In most instances it shows plainest in the massive, softer beds of sandstone which were least able to resist the forces placed upon the whole stratigraphic section in which they occur.

The fact that the clastic sediments are in some cases irregularly deposited, showing wave-action or current-action, in the form of cross-bedding or false-bedding, coupled with the various irregularities due to weathering, leaves ample room for overlooking the evidences and importance of structural distortion. A close observation of the exact nature of the rock structure will reveal that cross-bedding or false-bedding, concretionary segregation of mineral matter, spheroidal weathering, and small rock-folds due to weathering, such as described previously by Campbell,¹ can readily be recognized as such. Distortion due to deep-seated folding under a heavy load likewise can be recognized and is of definitely

¹Campbell, Marius R., Rock Folds Due to Weathering, Jour. Geol. Vol. XIV, Nov.-Dec., 1906.

PLATE II.



Fig. 1. Distorted sandstone (Pennsylvanian) on south flank of dome in south portion T. 21 N. R. 10 E. Osage County, Oklahoma. Bedding planes A-B and C-D are severely distorted in parallel fashion. Distortion plane G crosses the upper bedding plane and ends by a curve in the central stratum.



Fig. 2. Distorted sandstone (Pennsylvanian) near the top of the Cushing anticline on Jackson Barnett lease N. $\frac{1}{2}$ S. E. Sec. 5 T. 17 N. R. 7 E. Creek County, Oklahoma. Note that bed A-B is thinned down at point C and that bed E-F is correspondingly mashed at point G.

different character. In the case of distortion, the massive layers frequently show "distortion planes" and in other instances the bedding planes are bent and warped, showing a similar condition, on a lesser scale, that is so evident in a polished slab of marble which was at one time stratified limestone. There can be no question about the distortion of rock structure in so intense a metamorphic action as one which produced marble from limestone. In the case of localized minor distortion on the gently folded rocks of the oil fields, however, only the initial stages of this change is evident, and then only as an exception to the rule. It is observable under special conditions with respect to the nature of the fold and to the failure of certain individual strata to resist compression uniformly. In making observations for distortion on these milder types of folds, the observer should search especially for certain layers of rocks, particularly the softer beds of sandstone, which, due to their inability to preserve their original forms, have held a permanent record of the forces of compression to which they have been subjected. It is not every structure that will have such beds exposed on the surface. They are more apt to be found in areas where massive sandstones of varying degrees of resistance now lie at the surface. For the purpose of identifying distortion as contrasted to false bedding, the reader should carefully note the accompanying photograph which shows a distortion plane cutting across a bedding plane producing a slight off-set. This proves the distortion plane a structural feature and of a later date than the deposition.

This brings us to the question of whether or not, when distortion is definitely recognized, it is due to compression caused by the weight of overlying sediments. In other words, is it an expression of consolidation and settling following deposition? In reply the writer wishes to state that he has given considerable time and observation to the question of whether distortion of the degree here described is confined to the areas of local folding or is generally present in the strata throughout the oil country. He has concluded that it is characteristic of the areas of local folding; that it occurs on the axes and on the flanks of local folds of various

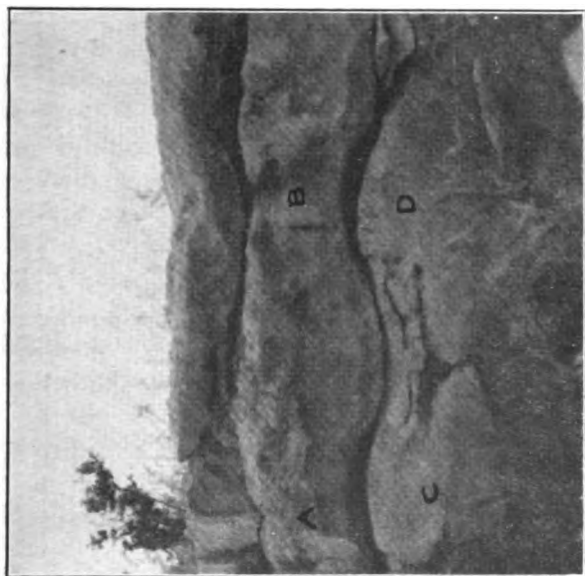


Fig. 1. Limestone beds (Pennsylvanian) south side, west end of structure in Burbank Field. Sec. 6 T. 26 N. R. 6 E., Osage County, Okla. Bed A-B is thinner at points C and D of the lower stratum. Note thicker portion between points A and B compensated by thinner portion between C and D showing adjustment later than time of deposition.



Fig. 2. Detached piece of sandstone (Pennsylvanian) from distorted bed showing typical curved or cup-shaped outline. Sec. 26 T. 23 N. R. 7 E., Osage County, Oklahoma. Distorted sandstone in place at top of hill.

types. It is frequently, and perhaps most often observable fairly well down the flanks or anticlines. A sandstone that shows distortion on a local fold, tends to lose its characteristic warped or mashed structure when its outcrop passes beyond the area of deformation. In areas remotely removed from local folding where the rate of dip clearly is uniform and constant, the writer's experience indicates that the different strata are undisturbed from their original form of deposition except as altered by settling, weathering and erosion. In other words, distortion of the nature to which the writer refers is, in such areas, conspicuous by its absence.

For some years the search for new oil pools in the Mid-Continent field has been confined largely to the areas where the outcropping of strata were sufficiently complete to define the nature of the folding. In such areas, differences of opinion on the nature of the structure have been chiefly a matter of the degree of accuracy in mapping. But in the future, drilling will be done in districts where the rocks are largely concealed and where the evidence of structure is incomplete. In such cases, observation of distortion is applicable even though it merely be the evidence on which core-drilling is done to define definitely the true structural conditions. Distortion of a stratum in any particular district is a raised finger of warning signifying that in this vicinity the strata have yielded to forces which have given them an upward lift of more or less importance.

In Volume I, of the Bulletin of the Southwestern Association of Petroleum Geologists, the writer delivered a paper entitled "The Vertical Component in Local Folding." He still maintains, and has been supported in his opinion, that the theory set forth on that occasion is substantially correct: that in the zone of observation the main application of the forces of local folding have been vertical rather than lateral. It is believed that the local folds of the Mid-Continent oil fields are not the result of tangential pressure moving outward from an area of maximum lift, such as the Ozark and Arbuckle areas, but that these smaller folds are the result of the same pressure that produced the larger lift; that they are smaller expressions of the same thing and not secondary

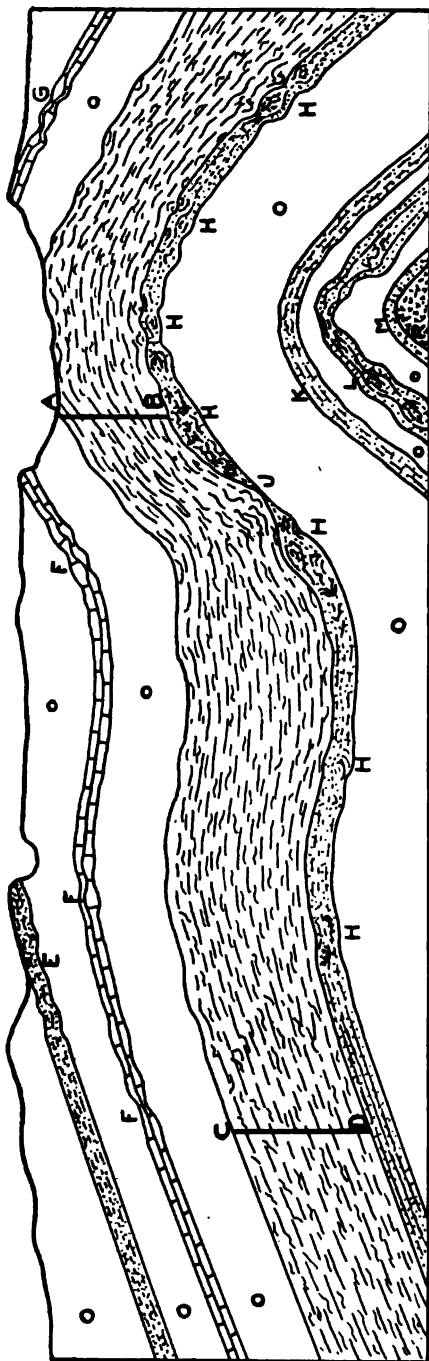


Plate IV. Cross-section illustrating deformation and distortion in Mid-Continent Fields. Note slight distortion of limestone at points F and G and sandstone at points A-B is thinned down below normal thickness shown at C-D. Sand at point J is mashed out and thickened in adjacent portion. Sandstones M and K are resistant beds not distorted. The granite core at point R is folded in conformity with the clastic rocks above.

results; that they were probably coincident and represent areas of failure to withstand deforming forces, the components of which were essentially vertical.

In the case, for instance, of the local structures of Kansas and Oklahoma, the writer believes that each of the domes, anticlines, terraces, noses, etc. that stand separate and distinct from all others, is an expression of the initial stage of folding due to an uplifting force which culminated or reached its maximum orogenic development in the central Ozark, Arbuckle and Ouachita regions. The deep seated flow of rocks toward that area of least resistance relieved the pressure from the adjacent smaller folds and thus, instead of the central area being the cause of their development, it really stopped the folding in the smaller areas. The local folds were relieved and arrested when the pressure was released to the larger area of structural failure. The nature of the folding is consistent with this idea and here the localized distortion on the flanks of anticlines has a scientific bearing that points to the same conclusion.

There is considerable evidence that compression incident to folding has reduced the normal thickness of the stratified section in the areas of local deformation. Well logs on the structures show a shortened or abnormal interval from the surface down to the oil sands. Well logs off the structure in normal areas, show a greater thickness for the same sediments. Recently in discussing deformation or distortion with the geological department of the Marland companies, the writer learned that in the Ponca City region, the sedimentary section is shorter on the folds than in the normal undisturbed areas of the same region. This condition was indicated also by Conkling² in his study of the Cushing structure and by Edwards³ in his cross-sections of the Burbank field. It seems to hold generally throughout Oklahoma. Thus, it is possible that the forces which caused the deformation acted upward from a deep-seated source and in doing so, the softer beds were

²Conkling, Richard A., *The Influence of the Movement in Shales on the Area of Oil Production*, Am. Inst. Min. Eng., Vol. 56, pp. 876-879, 1917.

³Edwards, O. M., *The Burbank Oil Field*, Am. Assn. Pet. Geol., Meeting March, 1922.

compressed into a lessened thickness and the incompetent strata preserve this record in the form of distortion.

A further suggestion is warranted that since a slight alteration of shale by compression may be indicated by chemical analyses showing the loss of combined water, then a close chemical study of the rocks on the local folds may prove the presence of slight localized metamorphism. In this connection there is a bearing on the theory of the genesis of petroleum and natural gas in connection with local deformation, as some authors have recently advocated. Moreover if it should be established that a greater degree of metamorphism exists on the local structures than in the territory immediately surrounding them, then such metamorphic action may have been more intense along the axes of anticlines and domes than elsewhere. This fact if demonstrated would account for the hardening of the oil and gas sands at the tops of structures as in many instances appears to be the case.

In the case of lifting a segment or detached load in the absence of friction or flexure, the law that "action is equal to reaction" applies and no extra pressure to speak of is necessary to raise such a load of overlying rocks. But in the case of lifting and folding from a given focus of pressure a condition exists similar to raising a tent from a central mast-pole; an extra pressure is necessary at the point of application due to the weight of the material on the flanks and to the resistance against folding. There is a tendency to break through at the point of pressure as is true in the case of an intrusive volcanic plug; thus the strata above the point of lift must transmit the pressure to higher strata and are consequently subjected to greatly increased compression, resulting in distortion and lessening of the thickness of the compressible beds above the area where the pressure is applied.

DISCUSSION

W. E. WRATHER: Mr. Gardner attributes the local thickening of strata of limestone shown in the photographs to compression. If this is true, the compression must have taken place before consolidation; or if it took place after consolidation, some evidence should be present in the form of fracturing, or of a crystalline character of the limestone due to metamorphism. Were such results noted?

J. H. GARDNER: The matter of metamorphism in connection with localized distortion is a subject the writer is greatly interested in and hopes to consider at our next annual meeting. At the present time, he is lacking in both thin sections and analyses which might throw light on the question that Mr. Wrather brings up with respect to a change in the crystalline character of the limestone beds on local structures. He is pleased to have this suggested field of research in connection with a study of the shales as referred to in the paper. The distortion is, however, of rather low degree at most, and the petrographic and chemical evidences may prove to be correspondingly slight and not easily demonstrated.

C. T. KIRK: The observations of Gardner in flat-lying strata might be repeated upon the many and intensified instances found about Lake Superior and in the Appalachian Mountain region. They have been analyzed more or less carefully by Leith in Bulletin 239, U. S. Geological Survey, and earlier in more or less experimental fashion by Willis, Annual Report XIII, Part 2, U. S. Geological Survey.

The epiclinal features are generally the result of the splitting or spalling of a rigid or competent bed confined between more yielding formations, and appears analogous to Leith's fracture folding phenomena.

J. H. GARDNER. Mr. Kirk's remarks with respect to the fracturing of the rigid beds between the yielding strata brings out an interesting angle of the question which appears very consistent with the observations here set forth and should receive further study.

F. G. CLAPP: Many evidences exist throughout the world, not always associated with local folding, of distortion produced by what might be termed isostasy on a small scale. Examples of such distortion may be interesting.

Many years ago W. H. Niles described in print some disastrous sudden expansions of rock that had taken place in, I think, Triassic sandstone quarries of the Connecticut valley of central Massachusetts. Great slabs of stone broke out without warning and with great force from the flat-lying beds in the bottom of the quarries, killing one or more men, if I recall correctly. The cause of the accident was supposed by Professor Niles to be due to the weight of the rock in the sides of the deep quarries transmitted through the rocks to the quarry floor, which yielded in consequence at the points of least resistance.

In Dickson County, Tennessee, farmers tell of several what they call "gas blowouts" which have occurred in recent years. The formation of the surface of the region is Mississippian limestone, dipping only slightly and comparatively thinly bedded. The valleys are several hundred feet deep and are V-shaped, only a few rods wide at the bottom. The "blow-outs" consisted of sudden expansion of the limestone with considerable noise over a few square yards at certain spots in the bottom of the deep-

est valleys, and the probable veracity of the reports is attested by the appearance of small holes, several feet across and a few inches deep in the limestone valley floor. Only slight gas pressure exists in any of the test wells put down in that part of Tennessee, and the wells are not deep enough to have high rock pressures. My view, on examining the spots, was that the "blowouts" were caused by the weight of the rock on the sides of the deep valleys, transmitted through the hills to the valley floors.

A third illustration was seen on my trips to central China, in northern Shensi Province, where narrow V-shaped valleys are numerous. The formation is Carboniferous sandstone and shale, exposed only in the lower parts of the deepest valleys, but where the solid rocks are overlaid by hundreds of feet of Recent loess, sometimes separated from the Carboniferous by a few feet of Pleistocene sandstone or gravel. A number of minute anticlines were seen by my associates and myself, the size being 5 to 15 feet in height and of about the same width. They generally extended transversely to the walls of deep side valleys, not far from where these valleys join the main valleys. Whether or not any of the distortions are parallel to the sides of the valleys is not certain. Some of the distortions extend from the Carboniferous rocks upward through the overlying Pleistocene deposits into the base of the loess. Mr. Fuller, who also examined the features, believed them to be due to the weight of the surrounding hills transmitted through the valley walls to their floors at the points of least resistance, where the distortion took place, and I am inclined to agree with him.

Summarizing, we have three regions (widely separated) from which distortionary features are here described, all of which would appear to be due to the weight of overlying sediments.

C. E. DECKER: A number of small sharp folds have been reported in northern Oklahoma associated with faults, some of which are said to be thrust faults. These folds and thrust faults seem to indicate a more marked lateral than vertical component in the stresses which deformed the rocks. I should like to ask Mr. Gardner if he found any marks on the surface of the limestones to indicate that they were deformed before the surfaces became hardened. It would seem to me that such thickening in heavy limestone beds could not take place unless the deformation took place before they hardened, particularly as they do not show close folding.

With reference to Mr. Clapp's statement, I should like to ask if he has attempted to calculate the amount of the stresses developed by the weight of valley walls, the pressure of which has been given as a cause for folds in the bottoms of many valleys. When the weight of the rocks in these walls is figured, it is so small that it is probably not strong enough to overcome the strength of the weaker shales and much less so the sandstone beds which are included in many of these folds.

FREDERICK H. LAHEE: There is one phase of this discussion which, I think, has been touched upon only by Dr. Decker. He stated the possibility that pronounced thinning and thickening of the limestone shown in one of Mr. Gardner's photographs may be the result of squeezing of the limy materials before these were consolidated. To my mind this is an important point which deserves serious consideration.

There are innumerable evidences of deformation, not only of limestone, but also of sandstone, shale, and other sedimentary rocks, before these rocks were consolidated. There is also an abundant literature on this subject. This kind of structure I have previously referred to as "contemporaneous deformation."* It may be due partly to the slipping and settling of some beds on others, a phenomenon which has been proved to occur in clayey materials on slopes of exceedingly low inclination; and it may be due partly to irregular compression of the sediments. However, in both cases it *precedes* consolidation and probably, also, in most cases it precedes the accumulation of any great overburden.

In the northern states there are many cases where the aqueoglacial sands exhibit small faults not continuous through the sand body. This sand is now quite unconsolidated, yet the faults are clear-cut and sharp. Two or three miles east of Donie, in Freestone County, Texas, are unmistakable evidences of crumpling, sliding, and fracturing of Tertiary clayey and sandy materials previous to their consolidation.

In looking at Mr. Gardner's illustrations, it seemed to me that at least 75 per cent of the structures shown were typical of contemporaneous deformation, that is, of local folding and faulting prior to and unrelated to diastrophic deformation. The picture showing a small fault in sandstone, sharply terminated upwards against more of the same sandstone, seemed to me adequate evidence that the displacement occurred during the deposition of this stratum.

Now, there is another point suggested by Mr. Gardner's interesting paper. We have recently had the experience of drilling high on a good anticlinal structure and finding that the sand, which is well represented on the flanks of the fold, is entirely absent on the crest. I am informed that this has been the experience of others in parts of Oklahoma and Kansas. I cannot explain the feature except as a consequence of folding during sedimentation. It would seem that the fold must have existed then as a low swell from which the currents carried the drifting sand and round the flanks of which this sand accumulated.

If we may explain the *absence* of a sand bed on top of an anticline and its presence on the flanks of the fold as the result of gradual arching during sedimentation, may it not be possible that the *thinning* of a sand or of a series of beds over an anticline may be similarly explained? I can

*Lahee, F. H., *Field Geology*, 1st ed., p. 75.

hardly believe that the slight bending which has produced the weak folds of the Mid-Continent field—folds in which we are accustomed to designate dips as so many feet per mile—has been mechanically sufficient noticeably to modify the thickness of single strata, or groups of strata, so folded. I believe that these marked variations in thickness of beds, as now measured, are due principally to conditions of deposition and differential settling.

MAX W. BALL: In the Duchesne region in the Uinta Basin, Utah, there are some extreme illustrations of what Mr. Gardner has called epiclinal movements. There are in the region considerable quantities of hydrocarbon known as ouijaite. This is a breccia consisting of angular fragments of limestone or limy shale in a cement of hydrocarbon of the gilsonite-elaterite series. In some places at least, the bed of limestone or limy shale has apparently been brecciated of the differential movements overlying and underlying beds. These beds, having been stronger or less brittle than the intervening bed, have moved without breaking, while the interlying bed has been broken into fragments, and the interstices filled by the hydrocarbons which are so abundant in the formation. At Duchesne, also, is a suggestion of the correctness of Mr. Knappen's statement that folding and faulting may have been rather generally caused by different horizontal movement. The numerous faults along the Clive anticline have much greater horizontal than vertical throw. There are strike faults along and parallel to the axis of the anticline. The vertical components are from 5 to 200 feet, the horizontal movement parallel to the trace of the fault plane is in some instances as great as a mile.

WALLACE E. PRATT: I desire to learn a little more about Mr. Gardner's Greek word "epiclinal." "Epi", I have thought, means "on," "clinal" means "inclined, tilted or leaning." It does not mean folded. Yet clearly Mr. Gardner uses epiclinal to indicate "on the fold." Would not "epi-anticlinal," under the conditions stated, be a more exact term?

C. K. LEITH: (In letter to Mr. Gardner).

Your paper seems to be very interesting and suggestive, but I do not feel that I have enough special knowledge of the territory you have in mind to make any definite constructive suggestions. There is no doubt that minor structures are often very useful as a key to the major structure, but it is also true that in some places there are local disturbances due to original sedimentation, consolidation, or secondary deformation, which are apparently unrelated to the major structures or may exist in otherwise flat and undisturbed beds.

Your paper seems to be written mainly with the idea of calling attention to this field of investigation, but you do not go into specific inferences that might be drawn from the specific structures.

GEOLOGICAL NOTES

POSSIBLE OIL IN SOUTHERN UTAH

The discovery of light oil of good grade in southern Utah and the knowledge that there are some large anticlines in that region has attracted oil operators to that part of the State. Oil has been obtained from wells in two districts in Utah, one on San Juan River, some miles west of the town of Bluff, in San Juan County, the other near Virgin City, in Washington County. Little oil has been produced commercially in either of these districts, however, partly because of the great difficulties of transportation but mainly because of rather unfavorable geologic conditions.

The possibility of obtaining oil in southern Utah in the region between and somewhat north of the two small oil fields just mentioned was investigated during the summer of 1921 by the United States Geological Survey, Department of the Interior. A party under the direction of R. C. Moore made a reconnaissance examination of much of Kane and Garfield counties and completed a detailed survey of the large structural dome in eastern Garfield County known as Circle Cliffs. The essential objects of the survey were to locate structural features that indicate favorable places for prospecting for oil, to trace accurately the geologic formations that are exposed in the region, to examine the rocks for indications of oil, and to make a special study of the structure of the Circle Cliffs.

The surface rocks in south-central and southeastern Utah consist chiefly of sandstone and shale that range in geologic age from Pennsylvanian to early Tertiary. As this region is almost a desert the rocks in it are exposed nearly everywhere, so that the surface geology and the structure may be determined readily. The chief geologic units are the brilliantly colored Tertiary formations that compose the highest plateaus and that may be seen in numerous exposures, as in the scenically famous Bryce Canyon, southeast of Panguitch; the Cretaceous beds, which form Kaiparowit Plateau and the prominent table-lands near the Henry Mountains; the remarkable thick, massive cross-bedded Jurassic sandstones that have been called by Gregory the Navajo and Wingate formations; the chocolate-colored and varicolored shales and sandstones of the Triassic and Permian; and the thick beds of Pennsylvanian limestone. The total thickness of the rocks exposed in this region is more than 13,000 feet. The younger rocks appear to lie mainly in the northwestern part of the region in the higher lands; the older rocks mainly in the southeastern part, in the canyons of Colorado and San Juan rivers and their tributaries.

Rocks saturated with oil or containing noticeable indications of it were found in parts of the Moenkopi formation (Triassic) in the Circle Cliffs, and showings and seepages of oil were found in the overlying Shinarump conglomerate, also Triassic, in the Circle Cliffs and along Colorado River

above the mouth of the Escalante. Oil-saturated Moenkopi beds have also been found in the San Rafael Swell. The oil-bearing formation of the San Juan field is older than any rocks that appear at the surface in

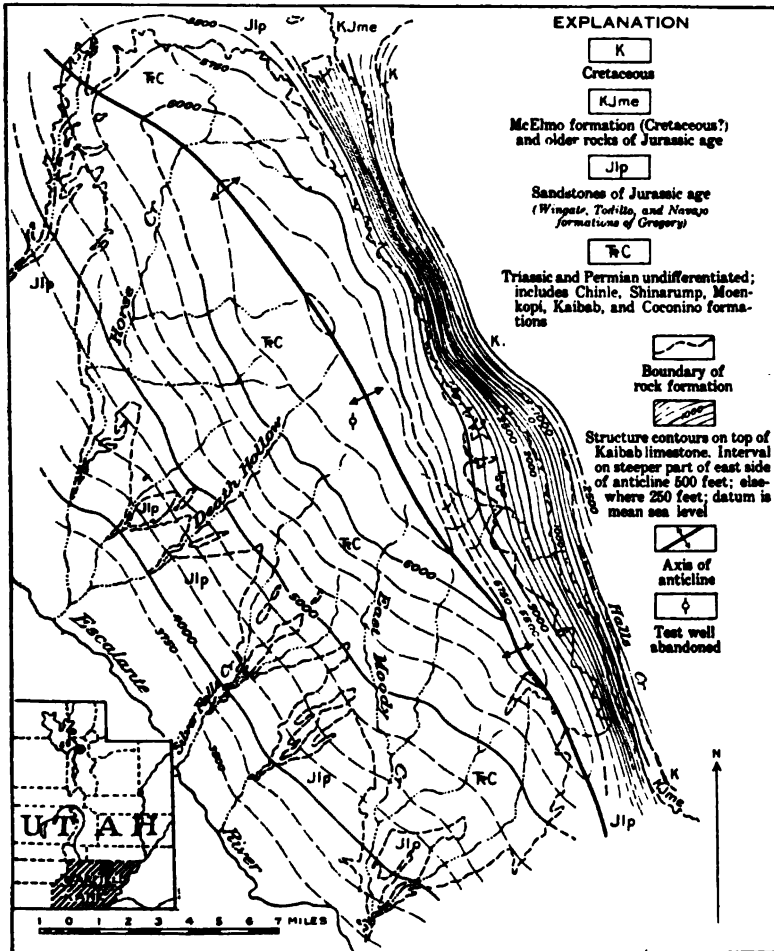


Fig. 1.

Kane and Garfield counties and is therefore not exposed here, but it should lie within drilling depth beneath Circle Cliffs.

The Circle Cliffs form one of the largest and best defined anticlines in

southern Utah. The cliffs, which are composed of Jurassic sandstone (the Wingate formation of Gregory) form an almost impassable wall that surrounds a lower elliptical area about 10 or 12 miles wide and 30 miles long. The longer axis of this cliff-walled inclosure trends north-northwest. The rocks within the cliffs belong to the Triassic and Permian systems, and the lowest formations (Kaibab limestone and Coconino sandstone) are found in canyons in the central part of the area. The Circle Cliffs consist of an asymmetrical anticline, whose crest, except at its north end, marks the main divide between the streams that flow southwestward into Escalante River and those that flow eastward into Hall's Creek. The anticline is really an especially high part of the great Water Pocket fold, which can be traced from a point beyond Colorado River on the south to Thousand Lake mountain on the north, a distance of about 80 miles. The beds on the southwest side of the Circle Cliffs anticline have a rather uniform dip, which for many miles amounts to about 250 feet to the mile. In the Kaiparowits Plateau, 25 miles distant, the beds are still inclined to the southwest, and the Kaibab limestone is there probably not less than 5,500 feet lower than in the central part of the Circle Cliffs. The beds on the east side of the anticline have a very steep dip, which averages about 30° but which is in places as much as 60° . By this downwarp the Kaibab limestone, which has an elevation of 6,500 feet in the highest part of the fold, is carried to a depth of 2,000 feet below sea level in a distance of 5 miles. The dip of the beds along the axis to the northwest and southeast is only about 70 feet to the mile, being thus much more gentle than the dip on either of the flanks. The closure in this anticline is at least 1,000 feet. At its south end the crest of the fold is rather sharp and narrow, but toward the north it becomes broader and less sharply defined. The detailed survey shows no minor domes or large terraces on the flanks of the main dome.

Near the town of Escalante there is a much smaller anticline with a steeply dipping west limb and a gently dipping east limb. The sandstone that has been called the Navajo by Gregory is the surface formation over the central part of this anticline. There are also in the region other minor structural features that have not yet been examined in detail. A test well started by the Ohio Oil Co., near the crest of the Circle Cliffs anticline in January, 1921, reached a depth of 3,212 feet in November, 1921, when it was abandoned. The drill penetrated about 1,660 feet of Coconino and Supai strata (Permian and Pennsylvanian?) and in the lower part of the well encountered thick limestone and sandstone that are probably equivalent to the Goodridge formation (Pennsylvanian), which contains the oil in the San Juan oil field. The failure to discover commercial accumulations of oil in these beds in this large anticline was a severe disappointment. Other test wells in the Circle Cliffs, even if drilled deeper, would probably not show different results, but this well by no means condemns other anticlines in this region, such as the geologically similar San Rafael Swell, farther north. The record of the Circle

Cliffs well is of high geologic value as an aid to the study of the Carboniferous strata in other parts of the Southwest.

As the Circle Cliffs well was started at a horizon below the oil-bearing sands in the Moenkopi and Shinarump formations, the lower parts of which crop out at the surface in Circle Cliffs, wells drilled to test the possibility of obtaining oil in commercial quantity from these sands must be located on favorable anticlines where the Moenkopi and Shinarump formations are not exposed at the surface and are within practicable drilling depth. In the anticline just east of the town of Escalante these sands lie about 1,700 to 2,000 feet below the surface.

Oil-bearing rocks occur in southern Utah, and prospecting in areas where the structure is favorable will be continued.

RAYMOND C. MOORE.

THE BELLEVUE POOL, LOUISIANA

The Bellevue pool is the youngest and in some ways the most wonderful pool in the North Louisiana oil field. It is in T. 19 N., R. 11 W., Bossier Parish, 17 miles northeast of Shreveport and the same distance southwest of the Homer pool.

The pool receives its name from the small village of Bellevue, 2 miles to the northwest, which was once the political center of Bossier Parish. The parish seat is now at Benton, 12 miles west. Bellevue is 6 miles north of Princeton, a station on the Louisiana & Arkansas Railroad. The wagon roads are unimproved. The most convenient way of reaching the pool is by automobile from Shreveport over 9 miles of hard surfaced pike to Red Chute, 10 miles of dirt road to Bellevue, and 2 miles southeast to Brown's farm, and at last, a 1-mile walk through woods and swamp to the wells. This 23-mile trip can be made in two hours.

Although a few wildcat holes had been drilled in the general area of east-central Bossier Parish, the first well-planned deep prospecting began with the completion of the Standard Oil Company's Heilperin No. 1 as a failure at 3,046 feet. This was in the year 1918 on a location in sec. 32, T. 20 N., R. 11 W., near Bellevue which, according to surface indications, seemed to be rather favorable. At the same time, or somewhat later, Mr. R. O. Roy, an operator and producer of Shreveport, was planning to drill about 4 miles farther south.

In 1919 and 1920 Roy's first two attempts, namely, Pease No. 1 in sec. 26, T. 19 N., R. 12 W., and Wyche No. 1 in sec. 14, same township, were abandoned as failures at 2,474 feet and 2,645 feet respectively, although each had penetrated the Nacatoch, Blossom, and Woodbine sand horizons and had found good showings of gas and some oil in the Nacatoch about 800 and 900 feet deep. In November, 1920, Mr. Roy completed a 5 to 15 barrel high-gravity pumping well at a depth of 2,173 feet (Woodbine formation) in sec. 7, T. 19 N., R. 11 W. This well never became a commercial producer but it gave evidence of oil in commercial quantity on the Bellevue structure.

Subsequently, in 1921, six deep tests were drilled within a radius of 6 miles of this first producer. None of these was far enough east up the dome to get production in the Nacatoch and none got encouraging showings in the lower sands. Of these holes, the Transcontinental Oil Co., Bliss & Weatherbee No. 1, in sec. 3, T. 19 N., R. 11 W., went to 3,014 feet, the Gulf Refining Co., Lyles No. 1 in sec. 13, T. 20 N., R. 12 W., went to 2,985 feet, and the Texas Co., Scanland No. 1 in sec. 29, T. 19 N., R. 11 W., went to 4,052 feet.

Meanwhile, Mr. Roy, with the co-operation of Mr. J. Y. Snyder, geologist, was drilling more test wells, principally shallow holes, and was finding the "gas rock" (Nacatoch) higher and higher toward the east. After drilling 10 or 12 holes, ranging from 200 to 400 feet deep, Messrs. Roy and Snyder, got the discovery well in the Nacatoch formation, with an initial production estimated at 6,000 barrels from a depth of 397 feet, 10 inches. This was the Hard Times Oil Co., Railroad Lands No. 7 in sec. 15, T. 19 N., R. 11 W., completed in the Nacatoch formation, November 13, 1921, about one year after the Roy-Smith No. 1 discovery well in the Woodbine.

The north half of T. 19 N., R. 11 W. is the area in which practically all of the drilling has been done and where all of the production has been found. Mr. Roy was the largest holder of leases in the area and the Louisiana Oil Refining Corporation owned more than $2\frac{1}{2}$ sections in fee. After the discovery in the shallow sand, The Standard Oil Co. of Louisiana bought several hundred acres of leases. Other companies who bought comparatively large acreage are the Texas, Humble, Sun, Transcontinental, Arkansas Natural Gas, and Gulf.

Since the discovery well came in, about 30 wells have been drilled in the area of sections 9, 10, 11, 14, 15, and 16 where shallow production is found. Three of these were failures in saltwater, on the edge of the producing center. The 27 wells located in a compact area $1\frac{1}{4}$ miles long and $\frac{3}{4}$ mile wide have produced 88,000 barrels of oil to April 1, 1922, covering the first three months of the life of the pool. Of this total, 57,000 barrels were pipe line runs and 31,000 barrels were in storage. On March 31, the following operators, named in order of producing importance, produced 1,580 barrels: Louisiana Oil Refining Corporation, R. L. Autrey, Standard Oil Co. of Louisiana, R. O. Roy, Chandler & Collins, Gulf Refining Co., and Humble Oil & Refining Co.

The oil contains about one per cent basic sediment and salt water, although in one edge well the salt water amounts to 80 per cent of the fluid. The estimates of initial production in the Bellevue pool have been too high in some cases because of the foamy condition of the gushers. One well made several million cubic feet of gas with the oil. A sample of the crude shows a gravity of 19.3 Baume and contains 2.5 per cent gasoline, gravity 63.6 Baume; 2.5 per cent naptha, gravity 54.2 Baume; 7.5 per cent kerosene, gravity 43.3 Baume; 12.5 per cent gas oil, gravity

33.5 Baume; 30.0 per cent spindle oil, gravity 27.2 Baume; 38.0 per cent lubricating oil, gravity 21.3 Baume; and 7.0 per cent loss and coke.

Topographically, the Bellevue area is a somewhat featureless plain, particularly over the shallow pool where the surface is about 215 feet above sea level. In wet weather a small meandering stream is inadequate for drainage, and the surface becomes a swamp. In one or two places, open "prairies" break the monotony of wooded areas. Farther away, more noticeably 3 to 5 miles north and west along Bodcau Lake and Bodcau Bayou, the surface is rolling and breaks off in the bayou bluffs which drop 50 feet or more. Bellevue would not be selected for an oil field because of its topography.

Nor would the shallow pool, as now developed, have been discovered by its surface geological features. The soil is gray sandy loam and clay, rather uniformly characteristic of nothing except Quaternary and Recent formations. Dips of beds exposed at the surface throw little if any light on the structure.

A more extensive examination, however, of the area surrounding the producing wells results in the discovery of pronounced stratigraphic features indicating distinctly favorable deformation. Township 19 North, Range 11 West, has long been mapped¹ as a Tertiary inlier surrounded by Quaternary. More than this, subsequent work by many geologists has established the generally accepted fact that the limestone concretions of the older Wilcox formation are surrounded by marine clays of the younger Lower Claiborne and also by probably still younger deposits of Upper Claiborne, all of which are completely encompassed by Quaternary and Recent formations. Although this stratigraphic sequence from an old center to a young periphery may not be traced out in every direction, the exposures of these formations are sufficiently numerous to indicate the nature of the general structure as that of a truncated dome. The proof of this structure is found in the logs of wells drilled in this part of Bossier Parish and the adjoining part of Webster Parish.

The top of the dome as mapped on the producing horizon of the Natchoch formation drops almost 1,800 feet in 6½ miles toward the northeast, or from 60 feet below sea level in the northwest corner of sec. 14, T. 19 N., R. 11 W. to 1,845 below sea level in the southwest corner of sec. 16, T. 20 N., R. 10 W. This is a dip of 275 feet per mile or about 3°. Toward the southwest it dips about 750 in 9 miles, or 83 feet per mile, or a little more than ½ degree. The dome has at least 600 feet of closure. Toward the west, it grades off onto the general level of the Sabine Uplift and toward the northeast it plunges off the Uplift into a deep syncline southwest of the Homer pool. The Bellevue structure may be described as a dome on the east side of the Sabine Uplift. Nowhere in the North Louis-

¹Veatch, A. C., *Geology and Underground Water Resources of Northern Louisiana and Southern Arkansas*, U. S. G. S. Prof. Paper 46, Pl. III., 1906.

iana territory does the Nacatoch come so near the surface without outcropping. On the present producing top of the dome, the Nacatoch is 289 feet below the surface, 60 feet below sea level, and has a structural relief of 200 feet. It is 500 feet higher than the Caddo structure, 600 feet higher than the Homer dome, 1,600 feet higher than the Haynesville fold, and 1,900 feet higher than the El Dorado, Ark., terrace.

The vertical section on the top of the Bellevue dome as now known shows a water sand under 80 or 90 feet of surface sand and clay; then about 150 feet of shale, probably Arkadelphia clay, representing the top of the Cretaceous to a depth of 250; then 50 feet or more of hard limestone overlying 10 to 20 feet of oil sand. Production is sometimes found in the limestone "cap"; sometimes in the underlying sand. Initial production ranges from less than 100 to several thousand barrels.

On the side of the dome, deeper test holes, such as the Texas Co.'s Scanland No. 1 in sec. 29, T. 19 N., R. 11 W., $3\frac{1}{2}$ miles from the top of the structure and 300 feet down the flank, find the top of the Nacatoch at a depth of 600 feet, the Blossom at 1,500 feet, the Woodbine at 2,100 feet, and probably Lower Cretaceous sands at 3,100 feet. All sands known to produce elsewhere in Louisiana fields are easily reached by the drill in the Bellevue pool.

Small portable rotary rigs are used. Eight inch casing is set below the shallow water sand near 100 feet and 6-inch is set in the "lime rock" above the pay sand near 300 feet. One 8-inch and one 6-inch pipe line owned by the Standard Oil Co. of Louisiana and the Louisiana Oil Refining Corporation have been laid to loading racks 4 miles south on the L. & A. railroad.

The gusher pool of heavy oil in the Nacatoch is considered only the beginning of production on this dome. The favorable structure, comparatively shallow depths to the three lower sands, and encouraging showings in the deep test, indicate a bright future for Bellevue.

Shreveport, La., April 12, 1922.

J. P. D. HULL.

A number of wells on the Bellevue dome have held up in production remarkably well. National Oil Company's (R. J. Barry, Trustee) Elston No. 2, in sec. 10, T. 19 N., R. 11 W., which came in with 1,000 barrels initial production has produced almost 40,000 barrels during the first six weeks of its life. It flowed 600 barrels daily the first eight weeks, 100 barrels daily the next two weeks, and is now flowing 300 barrels a day. It contains no basic sediment and no salt-water.

Drilling was originally done with "baby" rotary rigs, but better results seem to be had with cable tools, particularly with Armstrong rig No. 25, using gasoline as fuel.

Four days are needed to drill 300 to 350 feet where the first gas show is found in a limestone "cap" and 6-inch casing is set and cemented. After 10 days shut down to allow cement to set, the plug is drilled and

hole deepened 2 feet, or more, to the oil sand. The cost of drilling is about twelve hundred dollars.

Shreveport, La., April 18, 1922.

J. P. D. HULL.

WEBSTER PARISH GAS FIELDS, LOUISIANA

Within the last six months a gas field has been developed in Northern Webster Parish, Louisiana, that gives promise of being as large as the Bethany, Texas-Louisiana, field and half as large as the Monroe, Louisiana, field.

Drilling for oil in northern Webster Parish was commenced in January, 1919, by Mr. J. K. Wadley and associates, of Texarkana, Arkansas-Texas. Five holes were drilled by different operators in the area east of Cotton Valley with indifferent results as regards showings of oil and gas, before the discovery well blew in, making several million cubic feet of gas, several barrels of oil, and several thousand barrels of salt water. The well blew wild ten days, was then capped, but when reopened, had bridged over. It was abandoned because of the bad condition of the hole.

This well was drilled by the Louisiana Oil Refining Corporation and J. K. Wadley on the Gleason farm in sec. 13, T. 22 N., R. 10 W., 6 miles due east from Sarepta, a station on the Louisiana and Arkansas Railroad. The location was made in July, 1920, on the evidence of extended sub-surface work and of Tertiary and Quaternary dips on the surface. The first hole was junked at 1784 feet, but the second attempt blew in uncontrolled from the Blossom sand at a depth of 2793 feet, on February 4, 1921. It had to be killed and a second well, Gleason A-1, 100 yards away was completed at a depth of 2788 feet, in August, 1921. It met a worse fate, however, than No. 1, for it not only blew uncontrolled with the drill stem in the hole, but it formed a crater, caught fire, and from March 7 to April 7, 1922, was a boiling, burning lake of gas, oil, and salt water. On the latter date, coincident with the pumping of mud into the Gleason A-2 which had been drilled 100 feet away as a relief well and coincident with the blowing in of the Fullilove and Wadley, Martin No. 1 about a mile away, the crater subsided and the fire went out, although the escape of gas and fluid is still uncontrolled (April 15th.) None of the wells, therefore, at the discovery location is commercially productive. Gleason No. 1 was conservatively estimated as making 15 million cubic feet of gas, 50 barrels of oil, and 3,000 barrels of salt water. The oil had a gravity of 25 Baume and the water contained 7 per cent. sodium chloride.

The first well to be successfully drilled without being ruined by salt water was the Sinclair Oil Company's Mayfield No. 1, in sec. 20, T. 23 N., R. 9 W. This well had an initial production, September 20th, 1921, estimated at 10 million cubic feet of gas and a rock pressure of 1030 pounds per square inch. Since that time, four other large gassers have been completed, namely: Portland Syndicate, Munn No. 1 in sec. 1, T. 22 N., R. 10 W., gauged at 44 million cubic feet and 1210 pounds pressure,

Lloyd Harris et al., Giles No. 1 in sec 34, T. 23 N., R. 11 W., Raymond et al., Jordan & Young No. 1 in sec. 33, T. 23 N., R. 10 W., and Fullilove and Wadley, Martin No. 1 in sec. 12, T. 22 N., R. 10 W., each of the last three estimated as high as 30 million cubic feet initial production.

The Giles well is plugged full of cement, the Jordan and Young has the drill stem in the hole, but the Martin and the Mayfield will probably be connected by pipe line with the Haynesville oil field, and the Munn has been supplying gas for fuel at Haynesville for several months. The wells may be classed as dry gassers although the Mayfield sprayed a little oil having a gravity of 29.7 Baume and containing 6 per cent. basic sediment and water.

Production comes from the Blossom sand of the Upper Cretaceous, which is the pay sand in the Haynesville oil pool 5 miles to the east.

The total depth of the gas wells ranges from 2650 to 2750 feet and the structure is only 10 feet higher than at Haynesville, according to present development. It seems improbable that the Webster Parish structure is a continuous part of the Haynesville fold, though both appear to be high parts of a long low fold extending eastward from the northeast base of the Sabine Uplift. The sand so far drilled ranges from 2 to 18 feet thick. It is generally finely granular, calcareous, and soft. As at Haynesville, the top of the structure is surprisingly low as compared with nearby pools. It is 800 feet lower than the Homer dome 15 miles to the southeast and 1400 feet lower than the Bellevue dome 20 miles south.

The area enclosed by the five gassers is 11 miles long and 4 miles wide and contains no failures in drilling. The surface is partly hilly, partly bayou bottom land, ranging in age from the Claiborne ferruginous sands and clays of the Tertiary to similar formations of the Quaternary. Surface dips in the Eocene are only indefinitely representative of sub-surface structure 2700 below it in the Upper Cretaceous.

The pool is not at all clearly defined, although several salt water holes have been drilled to the southeast within 2 or 3 miles of the gas wells. Salt water has also been encountered four miles to the northwest and four miles to the northeast. Present development indicates a gas pool 11 miles long, east and west, across the north end of the parish. This long fold appears to have a productive structural relief of 40 feet, below which salt water occurs. Oil has been found near the salt water line in encouraging quantity, but no oil producers have been made because of proximity to salt water down the structure. There will be an active drilling campaign in northern Webster this summer.

Shreveport, Louisiana,

J. P. D. HULL.

April 15, 1922.

A NEW GULF COAST SALT DOME

About the first of April it became definitely established and generally known that Wheat No. 1 drilling jointly by Gulf Production Company and Snowden Brothers & McSweeney, on Wheat Ranch, 8 miles south

of the town of Richmond, Ford Bend County, Texas, had penetrated salt dome materials at a depth of less than 700 feet. Thus a hitherto unknown or unproven salt dome is discovered and may now be added to the list of previously known Gulf Coast domes. Similarly a new potential oil field is indicated for as yet no proven salt dome on the Gulf Coast can be eliminated positively from the ranks of petroleum producing possibilities. In the case of the new dome petroleum has, as a matter of fact, been encountered in the "cap rock" although probably not in commercial quantity at the present shallow depth. The oil is 22° B. in gravity, similar to the ordinary Gulf Coast product.

Although the locality is one in which the presence of a salt dome might well be suspected, since it is on a line with Damon Mound and West Columbia and at a logical distance north of Damon Mound, yet the surface evidences of this new dome are meager and have failed to impress a number of careful students of salt domes who have examined them. There is no topographic evidence of uplift nor any solution depression—characters which are common to known salt domes. Big Creek, a stream of secondary importance, flows southward past the well and across the probable top of the dome, but the general area is a high inter-stream divide extending about north and south between San Bernard and Brazos rivers.

Along Big Creek near the new well are several seeps of inflammable gas with small springs of mineralized water. Both gas and water yield an odor of hydrogen sulphide. Larger and more active gas seeps with similar "sulphur water" springs elsewhere in the Gulf Coast country have, on several occasions in the past, led to drilling exploration which failed to find either salt-domes or petroleum. An old water well less than 100 feet deep near the site of the discovery well yielded water charged with hydrogen sulphide, and it is alleged to have been drilled through an unusual amount of rock. The discovery well is said to have drilled in rock almost continuously from the surface to the present depth indicating a degree of induration which is rarely encountered in the Gulf Coast formations except over salt domes.

Credit for the discovery goes most appropriately to Mr. L. P. Garrett, Chief Geologist for Gulf Production Company, upon whose judgement the decision to drill this prospect and the location for the first well were made. Messrs. Sorelle & Meyer, Houston Brokers, blocked the acreage around the gas seeps and turned it over to Gulf Production Company and Snowden Brothers & McSweeney, jointly. The decision for Snowden Brothers & McSweeney to participate in this undertaking rested with Mr. J. P. Shannon, Supt., who also drilled the discovery well at Pierce Junction last year, on his first venture into the Gulf Coast fields. Mr. Lee Hager, a prominent Houston geologist, also realized the significance of the surface showings in the vicinity of the new discovery as is evidenced by the facts that several years ago he purchased something over 600 acres of fee land around the gas seeps and that he still retains his royalty interest in this land.

In spite of the foregoing statement that all Gulf Coast salt domes are possible future oil fields, and in spite of the showing of oil in the discovery well it would be incorrect to assume that the dome just discovered in Fort Bend County, (which might well be called the Big Creek Dome), is certainly and speedily to become the site of a new oil field. If the cap rock fails to produce commercially and exploration of lateral sands around the periphery of the dome becomes necessary before production is obtained, the search, even though ultimately successful, will probably require a period of years of preliminary drilling. After all, less than half of our known salt domes are commercially productive of petroleum, and the new discovery although certainly a salt dome may or may not develop into an oil field.

Houston, Texas.

WALLACE E. PRATT.

On May 15 Wheat No. 1 had been completed at 710 feet in salt and was rated as a 100-barrel pumper.

W. E. P.

A SCHEDULE FOR THE FIELD DESCRIPTION OF SEDIMENTARY ROCKS

A schedule for the field description of sedimentary rocks has just been prepared by a subcommittee of the Committee on Sedimentation of the National Research Council.

The object is to furnish a check list to aid the field description of sedimentary rocks. It is not intended to indicate what are the most important characters to describe but to present an outline broad enough to cover any special case, yet of such size that the printed form can be pasted in the back of a note book. Theoretically of course such an ideal is quite unattainable. The characters which could be recognized in any sedimentary rock are numberless, and all that a schedule like this does is to formulate the points of view and the problems that appear uppermost at the time.

What is true of the wide range of characters to be observed, is even more true of the relations of characters. These are necessarily more numerous than the characters, and their determination much more important; for most if not all of the progress of knowledge is based essentially on the discovery of new relations between facts. While the user of the schedule should be reminded constantly to look for relationships, the impression should be avoided that in this or any other respect the schedule may be relied on as final or complete. All it aims to do is to serve as a guide to those less familiar with the subject and as a systematic jog to the memory of the more experienced.

An attempt has been made to prepare this schedule in such form that it would be applicable to any part of a stratigraphic section from all of an extensive exposure down to the minutest lamina or lenticle. In practice it is generally best to begin by determining the largest lithologic divisions, according to the judgment of the observer, of an exposure as a whole, and recording their characters, following the sched-

ule as far as it can be applied. Then subdivisions of the next order should be determined and described, and so on down to the smallest units observable. This will not be so long a process as it may seem, since many characters would be observable only in the smaller divisions.

The feature in the schedule which is considered most important and fundamental is the emphasis on quantitative results. It is not intended to encourage a super-refinement beyond the needs of the investigator. In very many cases a mere quantitative estimate will suffice, but in the great majority of cases quantitative results are the only ones that can be reworked in the office by the geologist himself or permit of new interpretation by others. To build up a permanent record for the future, therefore, quantitative data are essential.

Underlying any system for the description of sedimentary rocks must be some system of classification of the characters to be described, but in a practical system it is necessary to avoid a philosophically rigid and perfect a system which might be so abstract as not to be readily applied.

An important feature of field work which does not belong in the schedule is the collection of specimens for laboratory study. Any material collected for laboratory study should probably serve one of three purposes: (a) To form part of a complete series representing every bed or what appears to the collector to be every distinct type of rock, (b) To represent some peculiar type of rock which the collector can not sufficiently identify in the field, or which he recognizes to be new, and (c) To help in the testing of hypotheses formed in the field as to the origin of the characters of any rock. In general, specimens should not be picked up hastily here and there in the hope that laboratory study, unsupported by careful field study and hypotheses, may reveal their origin.

Among suggestions which the committee received but which are not incorporated in the schedule, the largest number concerned secondary features or what might be called the indirect expressions of the features of the rock. In formulating the purpose of the schedule it was decided as desirable to make it bring out only those features which might ultimately serve to determine the conditions under which the rock was formed, features acquired later (epigenetic) being considered only with a view to disentangling them from the original features. Such things as jointing, disturbance and distortion of beds by movement subsequent to burial, slickensiding, erosion forms, weathering, color banding by ground waters, topographic and vegetational expression of lithology were omitted, as they do not fall within this purpose. Any of them may be expressions of the primary characteristics of the rocks but are significant for the purpose only in so far as the characteristics they express can be directly determined. Though they may therefore be of use to the geologist in the field, as a clue to certain physical features he should look for, they may be excluded from consideration as ultimate in the description which is in mind.

Moreover, it is evident that if one starts out to use such features it would soon be necessary to prepare a schedule for the whole range of field work including tectonics, igneous geology, physiography and physiographic processes, ground water, etc.

With the above formulation of the object of the schedule in mind the committee hesitated for some time over the question of describing *shaly structure*. The final conclusion was that it is not known to what shaly structure is due—whether to the manner in which the shale bed was deposited or to forces to which it has since been subjected—and that until this is decided it would not only be justifiable to include it in the schedule but that in so doing it might be possible to help solve the problem of the origin of shaly structure. Users of this schedule are therefore urged to pay special attention to this problem, and it would be very desirable for observers to send to the committee any material that illustrates their conception of shale or that seems to throw any light on the origin of shaly structure. It has been placed under *C. 1.*, where it belongs if it belongs in the schedule at all.

Color is a property that is listed in several places in the schedule. The need for some accurate and generally accepted method of describing color is keenly felt by geologists—that it is, in fact, the part of the schedule as planned which has received the heartiest welcome.

Elements of the problems of color standardization are very clearly and simply presented in Technologic Paper 167 of the U. S. Bureau of Standards, "An examination of the Munsell color system," by Irwin G. Priest, K. S. Gibson, and H. J. McNicholas, which may be had from the Superintendent of Documents, Washington, D. C., for 10 cents. This paper makes it evident that years will probably be consumed in the merely mechanical work of standardizing the entire color scale, but Mr. Priest, the senior author of the paper, has approved the use in the meantime of some of the less perfect systems, such as that of Robert Ridgway, "Color standards and color nomenclature," published by the author at Washington, D. C., in 1912 and for sale by A. Hoen & Co., Chester, Chase, and Biddle Streets, Baltimore, Md., or the Munsell system, described by A. H. Munsell in "A color notation" and represented in the "Atlas of the Munsell color system," Munsell Color Co., Printing Crafts Building, 8th Ave. & 34 St. New York City. The positions in the final color system of the colors in these systems can be determined when the final system is established, and thus all color descriptions based on them can be related to the final system. It is hoped soon to prepare a set of colors small enough to be mounted in a field notebook, and in submitting that its use will be discussed somewhat more fully.

Discussion of the preliminary schedule brought out the fact that abstractly divisions *C.2* and *C.4* of the schedule differ only in the scale of the characters dealt with, but as this difference in scale indicates definite geologic distinction it has been allowed to stand.

In subdivision *D. 1. c* quantitative methods have been recommended for

measuring the shape of the larger constituents of sedimentary rocks, mainly pebbles and larger fragments. These methods are based on the work of C. K. Wentworth, reported in preliminary form at the meeting of the Geological Society of America (see abstract in Bull. Geol. Soc. America, vol. 32, No. 1, p. 89, 1921) and to be published in greater detail as Bulletin 730-C of the U. S. Geological Survey. Although Mr. Wentworth has devised instruments for making these measurements, a consultation with him showed that it is possible to make rather accurate estimates of the dimensions to be determined. Though the selection of dimensions to be measured is only preliminary and will probably be modified and improved by Mr. Wentworth and others, his system is recommended as by far the best and most precise now available.

The schedule is not regarded by the Committee as in any way final. The experience of those who use it in the field and new discoveries or changes in the leading problems of the subject are bound to call for modifications which will make new editions of the schedule necessary; and suggestions to this end will be welcome. Such suggestions should be sent to the chairman of the subcommittee, Dr. Marcus I. Goldman, U. S. Geological Survey, Washington, D. C.

Copies of the schedule in convenient size (5 by 8 inches) for use in notebook may be obtained on application to Dr. Goldman.

A Schedule for the Field Description of Sedimentary Rocks.

A. External form of the rock unit. Lenticular, persistent, very regular in thickness, etc.; dimensions.

B. Color. Color of unit as a whole, wet or dry, according to Ridgway or Munsell color system, or color card of this committee.

C. Bedding.

1. How manifested: Sharp, by partings, by difference in texture, color, etc.; transitional; shaly (see introductory note).

2. Shape of bedding surfaces: plane, undulating, ripple-marked, etc.; irregular; if not plane, give details of form and dimensions of features.

3. Thickness of beds: Comparative thickness; different orders. Relation of thickness; rhythmic; random. If variable, relation between thickness and composition, bedding, etc.

4. Attitude and direction of bedding surfaces: Horizontal, inclined, curved. Relation to each other: Parallel, intersecting, tangential; angles between different attitudes and directions; dip, strikes; dimensions; relation of size, composition, shape, etc., to attitude and direction; relation of composition to different types of bedding.

5. Marking of bedding surfaces: Mud cracks, rain prints, bubble impressions, ice-crystal impressions, trails, footprints, etc.

6. Disturbances of bedding: Edgewise or intraformational conglomerates, folding or crumpling of individual beds before consolidation, etc.

D. Composition.**1. Inorganic constituents.**

a. Mineralogy or lithology of principal constituents.

b. Size: Prevailing size if fairly uniform; range in sizes if not; proportions of different sizes as determined by sieving where feasible; distribution of sizes with relation to other features; vertical and lateral variations in size.

c. Shape: Crystalline (automorphic), angular, subangular, subrounded, rounded; relation of shape to size, material, position in beds, etc. For quantitative results on pebbles, etc., estimate or measure radius of curvature of sharpest edge, mean radius, and maximum and minimum diameter.

d. Character of surface: Glossy, smooth, mat, pitted, chatter marked, etc.

e. Orientation: With respect to bedding; with respect to life dimensions with respect to bedding to each other, etc.

f. Chemical and internal physical condition: Fresh, weathered, decomposed, cracked, etc.

g. Packing: Closeness and manner.

h. Pore space.

i. Cement: Present or absent; proportion; composition; variations in composition vertically and laterally and in relation to other characters; disposition with respect to bedding, fractures, etc.

j. Color: Wet or dry; location, inherent or as a stain in constituents or cement; variations and their relation to other factors, as composition, porosity, bedding, fracturing, fossils.

2. Organic constituents.

a. Kinds.

b. Size: Does the distribution of sizes show effect of mechanical deposition?

c. Condition: Entire, fragmented, partly dissolved, etc. Relation to kinds.

d. Distribution: With respect to character of beds, kinds of organisms, bedding, evidence of burrowing, etc. habits, possible manner of death, etc.

e. Orientation: With respect to bedding; with respect to life

E. Concretions.

1. Form, size, color, composition, and their variations.

2. Internal structure; central nucleus organic or inorganic; central hollow; homogeneous; banded horizontally, concentrically, etc.; radial; compact; vesicular.

3. Boundary against country rock: Sharp, transitional with or without change in character.

4. Relation of bedding to concretions: Continuous through concretions, deflected above, below, or both; thinned above, below, etc.

5. Distribution: Random; regular; if regular, intervals between groups (layers), vertically and horizontally; differences between characters of concretions in different groups (layers). Relation of distribution to other characters, as mechanical, chemical, or organic composition of country rock; jointing, fissuring, folding, etc., of country rock; topography; ground-water level; etc.

Note.—Define all terms that might be at all uncertain. Use metric units if possible. Describe first the largest units recognized, then those of the next order. and so on down to the smallest.

NOTE ON "A REVIEW OF OIL AND GAS POOLS IN NORTH LOUISIANA TERRITORY" BY J. P. D. HULL AND W. C. SPOONER.

WALLACE E. PRATT: Mr. Washburne has suggested that the anhydrite in the Lower Cretaceous rocks at Pine Island which Mr. Hull has described has heretofore not been recognized as a possible original source of the salt of our Gulf Coast salt domes. I should like to recall the fact that Dr. E. T. Dumble has previously recognized the gypsum-anhydrite horizon of the Lower Cretaceous as a possible source of the salt in the salt domes of the Gulf Coast, although I cannot make exact reference to the publication.

REVIEWS AND NEW PUBLICATIONS

HANDBOOK FOR FIELD GEOLOGISTS: By C. W. Hayes and Sidney Paige John Wiley & Sons, Inc. The third edition of this well known handbook has been thoroughly revised by Sidney Paige. It contains 166 pages and is sold for \$2.50.

A HANDBOOK OF THE PETROLEUM INDUSTRY: By David T. Day and others. John Wiley & Sons Inc. This treatise on the petroleum industry is the work of twenty contributors and will be published in May.

MAP OF WEST VIRGINIA: A new edition of the map of West Virginia by the West Virginia Geological Survey, Morgantown, W. Va., scale 8 miles to one inch is purchasable for \$1.00. It shows the location of coal, gas, limestone, and iron ore deposits.

PETROLEUM ENGINEERING IN THE BURKBURNETT FIELD, TEXAS: By H. W. Bell and J. B. Kerr, of the U. S. Bureau of Mines. This report of the Bureau of Mines is being published in the weekly numbers of the Oil and Gas Journal commencing March 24th. The majority of the reports of the Bureau of Mines are published by Chambers of Commerce, Conservation Commissions, and in various trade journals. Government work is supposed to be done for the benefit of all citizens and taxpayers and it is very doubtful if even interested geologists can learn of these various publications without keeping in constant communication with the branch offices of the Bureau.

A TREATISE ON PETROLEUM: By Sir Boverton Redwood, J. B. Lippincott Co. The fourth edition of this valuable work has been published with the co-operation of the U. S. Geological Survey and of many other institutions and individuals. The cost is \$39.00. Mr. O. B. Hopkins was one of the chief contributors for the Geological Survey. The three volumes including index and extensive bibliography comprise 1,368 pages.

MAPS OF SLICK AND LYONS-QUINN-DEANER FIELDS: The Chamber of Commerce, Bartlesville, Okla., has published production maps of the Slick field and of the Lyons, Quinn-Deaner fields which are white paper prints with blue lines. The elevation of wells in the Slick field are given, but no data except the location of the wells in T. 11 N., R. 11 E. The cost of the maps is 25c each. A report on the Slick field in 7. 15-16 N., R. 10 E., is in preparation.

Brady, G. S. The Mendoza-Neuquen petroleum fields. Commerce Reports, Bureau of Foreign and Domestic Commerce, March 6, 1922, pp. 573-574. Gives location of the fields, characteristics of the oil, account of present operations, and brief discussion of possibilities of the fields.

Clements, J. M. Japan preparing to test areas considered possible oil bearing. Nat. Petroleum News, vol. 14, Mtr. 1, 1922, pp 48-0-48-P. Brief description of Japan's known fields, production statistics, and estimate of oil reserves.

- Cronshaw, H. B. *Petroleum*. London, John Murray, 1921. 110 pp. Monograph prepared under the direction of the Mineral Resources Committee of the Imperial Institute. Review of the world's petroleum resources with particular reference to the British Empire and prospects of development in regions still unexplored. Introductory chapter deals with the characteristics, occurrence, mining, refining and uses of petroleum. Gives statistics of production for the principal producing countries, small oil-field map of the world, and brief bibliography on petroleum.
- Jillson, W. R. *Conservation of natural gas in Kentucky*, Louisville, Ky., John P. Morton & Company, 1922. 152 pp. Describes the natural gas-resources and by-product industries of Kentucky, giving statistics of production, and discuss the causes of waste of natural gas and the necessity for immediate conservation. Closes with a brief selected bibliography on the production, utilization, and conservation of natural gas.
- Marsters, V. F. Peru far below production that might be developed. *Nat. Petroleum News*, vol. 14, Mar. 1, 1922, pp. 48G-48I. Gives history of the industry in Peru, details of development in each field, production statistics and discussion of possible future production. Also reviews possibilities in Ecuador.
- Ness, J. Canada's northern oilfields. *Oildom*, vol. 13, March 1922 pp. 43-51. Paper before the third annual convention of the Natural Gas and Petroleum Association of Canada. Gives location of the fields, topography and natural resources, geology, occurrence of petroleum and discussion of future prospects.
- Arnold, Ralph and English, Walter. Canada's hope for oil lies in Western Provinces, not in far north. *Nat. Petroleum News*, vol. 14, Mar. 1, 1922, p. 48C. Gives estimates for five areas of Canada made by comparing them to geologically similar districts in the United States where development has been sufficient to prove fairly definitely what the ultimate resources will be.
- Benson, W. N. An outline of the geology of New Zealand. *Jour. Geol.*, vol. 30, Jan-Feb. 1922, pp. 1-17. Based on the writer's presidential address before the geological section of the Australian Association for the Advancement of Science, 1921.
- Blackwelder, Elliot. Meager data on China and Siberia not promising from oil standpoint. *Nat. Petroleum News*, vol. 14, Mar. 1, 1922, pp. 48P-48R. Discusses possibilities in these countries.
- Branner, J. C. Brazil is territory untested and little known geologically. *Nat. Petroleum News*, vol. 14, Mar. 1, 1922, pp. 48-I-48J. Describes petroleum indications in Brazil and discusses possibilities.
- De Golyer, E. On the estimating of petroleum reserves. *Econ. Geol.*, vol. 17, Jan-Feb, 1922, pp. 40-45. On the value and reliability of such estimates.
- Dod, H. C. Petroleum in Victoria. *Ind. Australian and Mining Stand.*, vol. 66, Dec. 8, 1921, p. 1048. Reviews structural features of this part of Australia, which are known to be favorable for oil accumulation.
- Douglass, Earl. The oil problem in the Uinta Basin, Utah. *Salt Lake Min. Rev.*, vol. 23, Nov. 30, 1921, pp. 12-13; Dec. 15, pp. 14-15; Dec. 30, pp. 9-11; Jan. 30, 1922, pp. 13-14; Feb. 28, pp. 9-11; Mar. 15, pp. 11-14; to be continued
- Garfias, V. R. Intelligent prospecting in Mexico vital to stability of industry. *Nat. Petroleum News*, vol. 14, Mar. 1, 1922, pp. 48M, 48N.

Summarizes present conditions in the Mexican fields and discusses possibilities.

- Hager, Dorsey. Oil possibilities, Holbrook area, Arizona. *Mining and Oil Bull.*, vol. 8, Jan., 1922, pp. 23-26, 33-34; Feb, pp. 71-74, 81, 94; to be continued. Describes conditions in this field which would justify testing for oil, gives physiography of the area and gives sections showing stratigraphic relations. See also *Oil and Gas Jour.*, vol. 20, Dec. 16, 1921, p. 76.
- Howell, J. V. Some structural factors in the accumulation of oil in southwestern Oklahoma. *Econ. Geol.* vol. 17, Jan. Feb., 1922, pp. 15-33. Detailed study of structural relations in the region south of the Arbuckle and Wichita mountains and north of the Red River.
- International Petroleum Reporter. Mining engineers urge oil reforms. Vol. 1, March 1, 1922, pp. 13-14. Resume of the petroleum symposium of the American Institute of Mining and Metallurgical Engineers in New York, February, 1922. See also *Nat. Petroleum News*, vol. 14, Mar. 1, 1922, pp. 25-27. *Oil-dom*, vol. 13, March 1922, pp. 17-18.
- Jillson, W. R. Oil and gas possibilities of "the Jackson Purchase" region. *Kentucky Geol. Survey, Series 6*, vol. 6, 1921, pp. 191-220. Gives geology of the region, results of drillings, with well logs, and summary of oil and gas possibilities.
- Jillson W. R. The Sixth Geological Survey. An administrative report of the several mineral resource and general geological investigations undertaken and completed in Kentucky during the biennial period 1920-1921. Presented with ten separate miscellaneous geological papers by G. P. Merrill, Stuart Weller, W. R. Jillson, Stuart St. Clair, and Charles Stevens Crouse. *Kentucky Geol. Survey, Series 6*, vol. 6, 1921. 291 pp.
- Kemp, J. F. and Billingsley, Paul. Sweet Grass Hills, Montana. *Bull. Geol. Soc. Am.*, vol. 32, Dec. 1, 1921, pp. 437-478. Detailed geological study.
- Killick, V. W. "It can safely be set down that any geological estimate of the world's oil resources, at this time, is entirely premature." *Petroleum World* (Los Angeles), vol. 7, Feb. 1922, pp. 5, 7, 20, 22, 24.
- Miser, H. D. Mineral resources of the Weynesboro Quadrangle, Tennessee. *Tennessee State Geol. Survey Bull.* 26, 1921. 171 pp. Includes section (pp. 147-152) describing oil and gas occurrence and accumulation in the Waynesboro Quadrangle and discussing possibilities.
- Moffit, F. H. Geology of the vicinity of Tuxedni Bay, Cook Inlet, Alaska. *U. S. Geol. Survey Bull.* 722-D, 1921. 7 pp. Results of a study with particular reference to oil possibilities in this region.
- Moore, R. C. and Plummer, F. B. Pennsylvanian stratigraphy of north-central Texas. *Jour. Geol.* vol. 30, Jan.-Feb. 1922, pp. 18-42. See also under Plummer, F. B. and Moore, R. C.
- Nelson, W. A. Description of oil and gas areas in Tennessee and conditions affecting new areas. *Tennessee State Geol. Survey Bull.* 25, 1921, (Administrative report of the State Geologist, 1920) pp. 49-66. Paper before the American Association of Petroleum Geologists, Mar. 1921.
- Nelson, W. A. Report on the geology and structural features of Benton County as they affect oil and gas possibilities. *Tennessee State Geological Survey Bull.* 25, 1921, (Administrative Report of the State Geologist, 1920) pp. 41-45.

- Park, James. Geology and mineral resources of Western Southland. New Zealand Dept. Mines, Geol. Survey Branch, Bull. 23, new series, Wellington, 1921, 88 pp. Detailed geological study, including discussion of oil prospects.
- Petroleum World (London). Oil and gas in western Canada. Vol. 19, March, 1922, pp. 100-103. Shows "from the similarity of geological conditions in Alberta and other parts of western Canada to the usual conditions accompanying the hydrocarbons throughout the world, that great possibilities await the exploiters of petroleum and natural gas in the western fields."
- Plummer, F. B. and Moore, R. C. Stratigraphy of the Pennsylvanian formations of north-central Texas. Univ. Texas Bull. 2132, June 5, 1921, 237 pp. Maps and plates. Based on studies primarily concerned with the possible development of oil and gas in the North Texas Pennsylvanian area.
- Powers, Sidney. Solitario uplift, Presidio-Brewster counties, Texas. Bull. Geol. Soc. Am., vol. 32, Dec. 1, 1921, pp. 417-428. Regional geology, detailed geology, and discussion of origin of the dome.
- Pratt, W. E. Philippine Islands may be classed as possible oil bearing territory. Nat. Petroleum News, vol. 14, Mar. 1, 1922, pp. 48J, 48L. Gives location of known seepages and indications of oil and discusses possibilities.
- Redfield, A. H. Central America too little known to afford estimate of possibilities. Nat. Petroleum News, vol. 14, Mar. 1, 1922, pp. 48E, 48D. Estimation of the unmined petroleum reserves of Central America by comparison, as far as possible, of the structure of the unknown reserves with that of a supposedly analogous North American field whose reserves have been estimated.
- Redfield, A. H. West Indies may be considered to hold little deposits of oil. Nat. Petroleum News, vol. 14, Mar. 1, 1922, pp. 48E, 48F. Gives location of some promising areas and known structural characteristics of the islands, but states that on account of the lack of details of local geology satisfactory estimates are impossible.
- Robinson, H. M. Geologic structure and oil and gas prospects of a part of Jefferson County, Okla. U. S. Geol. Survey Bull. 726 F, 1921, 26 pp. Gives stratigraphy and structure of the area and suggestions to prospectors.
- St. Clair, Stuart. The oil pools of Warren County, Kentucky. Kentucky Geol. Survey, Series 6, vol. 6, 1921, pp. 103-148. Gives history of development, geology of the oil fields, occurrence and source of the oil, well records, and discussion of economic considerations.
- Scott, W. W. and Stroud, B. K. The Haynesville oil field, Claiborne Parish Louisiana. Louisiana Dept. of Conservation, Bull. No. 11, Jan. 1922, 26 pp. In co-operation with the U. S. Bureau of Mines. Deals with the underground conditions and methods of operating in this field, the purpose of the report being primarily to aid the operators in their development problems, especially those encountered during the drilling of the wells.
- Stalder, Walter. The Clervo anticlinal bow oil field of California. Eng. and Min. Jour., vol. 113, Mar. 11, 1922, pp. 409-413. Details of a geological study of a prospective field on the West side of the San Joaquin Valley.
- Vander Leek, Lawrence. Petroleum resources of California. California State Mining Bureau Bull. 89, 1921. 179 pp. Report written to

"take stock of the oil resources of the State and in particular to determine, if possible, the opportunity that exists for extending the productive area into districts that have hitherto been regarded as unfavorable." Gives general theory of the origin and accumulation of oil in California, description of the oil-bearing formations in the State and detailed discussion of possibilities in various areas.

Wagner, Paul. Oil in sight from Mexico's known fields 225 million. *Nat. Petroleum News*, vol. 14, Mar. 1, 1922, pp. 57-59. Reviews possibilities south and southwest of Tampico.

Wagner, Paul. Tehuantepec believed to be important field for future production. *Nat. Petroleum News*, vol. 14, March 1, 1922, pp. 39-40, 43. Brief description of geologic structure of the Isthmian fields, account of development and discussion of possibilities.

Washburne, C. W. and White, K. D. Colombia's possible oil fields extend over enormous territory. *Nat. Petroleum News*, vol. 14, Mar. 1, 1922, pp. 48K-48L. Gives history and present state of development in Colombia and discusses possibilities.

Weller, Stuart. Oil and gas possibilities in Caldwell County, Kentucky. *Kentucky Geol. Survey, Series 6*, vol. 6, 1921, pp. 221-231. Gives stratigraphy and structure, summary of drilling and discussion of possibilities.

Ambrose, A. W. Problems in developing prospects. *Internat. Petroleum Rep.*, vol. 1, Feb. 15, 1922, pp. 11-12. Paper before the Pan-American Petroleum Conference, Washington, Feb. 7, 1922. Discusses problems of drilling and production, transportation and storage, and refining of oil in the development of new fields. See also *Oil and Gas Jour.*, vol. 20, Feb. 17, 1922, p. 6 *Oil Age*, vol. 18, March, 1922, p. 25. *Oildom*, vol. 13, March, 1922, pp. 35-36. *Oil Field Eng.*, vol. 24, Feb. 1922, p. 56.

California State Mining Bureau. Summary of operations, California oil fields. Monthly chapter, Seventh Annual Report of the State Oil and Gas Supervisor, December 1921. 52 pp. Contains, in addition to the summary of operations in the State during the month, the following articles: Notes on the use of oil instead of water or mud fluid in drilling, by H. B. Thomson. A method for loosening frozen casing or drill pipe with oil, by W. W. Copp. See under those authors.

Copp, W. W. A method for loosening frozen casing or drill pipe with oil. Summary of operations, California oil fields. Monthly chapter, Seventh Annual Report of the State Oil and Gas Supervisor, December 1921, pp. 13-15. Describes procedure and cites examples showing the successful use of the method.

Edson, F. A. Diamond drilling in oil production. *Oil and Gas Jour.*, vol. 20, Mar. 10, 1922, pp. 90-92. Describes outfit, its use and advantages.

Fell, D. A. Oil shale and a future American industry. *Railroad Red Book*, vol. 39, Feb. 1922, pp. 379-382. Reprinted from *Financial Year Book*, Daily Commercial News, San Francisco, Cal., Sept., 1921, pp. 96-97. On the possibilities of the American industry and general methods of mining, retorting and refining, particularly those used in Australia at the present time.

Gray, Alexander. Oil exploration. *Canadian Min. Jour.*, vol. 43, Feb. 3, 1922, pp. 68-70. Review of Canadian oil problems and status of new development.

- Jillson, W. R. A new method of producing crude oil in Kentucky. Kentucky Geol. Survey, Series 6, vol. 6, 1921, pp. 149-154. Describes "oil mining" methods used in Estill County, Kentucky, where a shaft has been sunk and oil produced from it.
- Kessal, H. F. Conditioning a well for oil production. Ind. Australian and Mining Stand., vol. 66, Dec. 22, 1921, pp. 1135-1136; to be continued. Discusses the effect of the presence of water and its exclusion from oil wells.
- Oil Age. Core drilling improves rotary efficiency. Vol. 18, March, 1922, p. 10. Enumerates the disadvantages of the drive-pipe and the single-barrel core drill in rotary sampling, and describes the Elliott double-barrel core drill recently perfected for this purpose, giving its advantages.
- Pardo, C. W. Mexican oil production—some big wells. Texaco Star, vol. 9, Feb. 1922, pp. 5-10. Describes some of the famous large wells in Mexican fields and explains some of the difficulties of developing fields in Mexico.
- Smith, L. E. Opinions still differ as to value of flooding Bradford sand. Nat. Petroleum News, vol. 14, Feb. 15, 1922, p. 67-68, 71. Discusses various phases of the subject and gives opinions of operators in the field.
- Standard Oil Bulletin. A hole deep and dry. Vol. 9, Feb. 1922, pp. 14-15. An account of the drilling and abandoning of a hole in Kern County, California, which stands as the deepest to date in the State.
- Thompson, H. B. Notes on the use of oil instead of water or mud fluid as a mixing fluid in drilling. Summary of operations, California oil fields. Monthly chapter, Seventh Annual Report of the State Oil and Gas Supervisor, December 1921, pp. 5-12. Discusses some of the records, both of success and failure, in the use of oil for drilling, together with the manner of overcoming the difficulties presented.
- Wagner, Paul. Diamond drill may revolutionize high cost field test operations. Nat. Petroleum News, vol. 14, Mar. 8, 1922, pp. 39-40, 43, 45. On the advantages of the diamond drill in wild-catting and its successful use in Mexican fields. ,

THE ASSOCIATION ROUND TABLE

PROCEEDINGS OF THE SEVENTH ANNUAL MEETING OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS HELD IN OKLAHOMA CITY

March 9-11, 1922

The headquarters of the American Association of Petroleum Geologists during its Seventh Annual Meeting were at the Huckins Hotel. The technical and business sessions were held in the Elks Hall and the public lecture on Thursday evening in the Christian Church.

The first session was called to order at 10 o'clock Thursday morning by President George C. Matson. A cordial welcome and friendly greetings were extended by Charles E. Hall, Manager of the Chamber of Commerce, and by Dr. Irving Perrine, President of the Oklahoma City Geological Society. Following these greetings the papers of the regular program were presented in order.

The afternoon session on Thursday was occupied by several papers on "Production" two papers on "Diamond Drilling" and a rather extended discussion of professional ethics in petroleum geology.

On Thursday evening a public illustrated lecture was given at the Christian Church by Dr. Charles Schuchert on "The General Geology of South America." After this lecture the members and friends of the association were entertained at a smoker at the rooms of the Chamber of Commerce where the members of the Oklahoma City Geological Society were the hosts for the association.

On Friday morning several excellent papers on Oklahoma and Kansas were followed by a business meeting at which the report of the Secretary-Treasurer, Dr. C. E. Decker, and the Editor, Dr. Raymond C. Moore, were given. These reports will appear later in these proceedings.

Before the close of this session a Central Committee was appointed consisting of Max W. Ball, Chairman; Leon Pepperberg, Secretary; David Donogue, R. S. McFarland, A. L. Beekly, Fritz Aurin, F. W. DeWolf, K. C. Heald, Charles Taylor, W. E. Wrather, George C. Matson, W. E. Pratt, R. C. Moore, C. E. Decker.

Friday afternoon a series of excellent papers were given in a regional session on Texas, Louisiana, Mississippi, and Utah.

On Saturday morning a concluding business meeting was held at which the report of the Central Committee was made while Max W. Ball, Chairman, presided. Amendments to the constitution to define the method of election of officers, to determine the place for holding the annual meeting, to change the name of the association, constitute fellows, to drop members for non-payment of dues, and to increase the dues for associate members were not passed. Other amendments proposed to increase the requirements for associate members from twenty to thirty

hours of geology, to establish honorary membership in the association and to change the article dealing with publications so that the associate editors shall replace the members of the publication committee were adopted by the association. These changes will be submitted to a vote as required by the constitution.

Section IV of the By-Laws was amended to read as follows: "Any member who shall be guilty of flagrant violation of the established principles of professional ethics may upon the unanimous vote of the executive committee be suspended or expelled from membership provided that such person shall, before suspension or expulsion, be granted a hearing before the executive committee.

The report of the Resolutions Committee was read and this report will be found in the latter part of these proceedings.

In the election of officers for the ensuing year two nominations were made for president, D. W. Ohern and W. E. Wrather, the latter being elected for the presidency. Max W. Ball was the only nominee for Vice-President and Charles E. Decker and Raymond C. Moore were re-elected respectively to the offices of secretary-treasurer and editor.

The technical sessions of the association were continued the rest of the forenoon and into the afternoon with a number of interesting illustrated papers which provoked extended discussion, particularly the one on China and a structural paper.

Besides the smoker on Thursday evening the main social event was the annual dinner Friday evening at the Huckins Hotel with Dr. D. W. Ohern as toastmaster, and Dr. Charles Schuchert, Dr. J. B. Umpleby, Mrs. W. C. Kite and Mr. James Gardner as speakers. A violin solo was rendered by Mrs Frank Buttram.

The visiting ladies were entertained by a musicale at Mrs. Frank Buttram's, a line party at the theatre and an automobile tour about the city.

The reports of the Committee on Resolutions, the officers of the association, and the members of the standing committees for the coming year are given below.

The Committee on Resolutions presented the following report, which was adopted.

Resolution from Visiting Ladies.

The visiting ladies wish to thank the members of the local geological society and their wives for the many courtesies extended and the delightful entertainment provided, and take this opportunity of expressing their appreciation.

Respectfully submitted,
MRS. A. W. MCCOY,
MRS. C. E. DECKER,
Committee.

A general resolution was passed with reference to our officials at Washington, D. C., endorsing a continued increase in the activities of the Departments of State and Commerce with respect to the international petroleum situation.

Respectfully submitted,
A. C. VEATCH,
RALPH ARNOLD,
WALLACE PRATT,
International Relations Committee

After C. W. Washburne announced the establishment of the medal, the following resolution presented by Max W. Ball, was passed:

That the American Association of Petroleum Geologists endorse the movement of the American Institute of Mining and Metallurgical Engineers to establish a medal commemorating the discovery of the Gulf Coast oil region by Captain Anthony F. Lucas at Spindletop, Texas, on January 10, 1901; said medal to be granted on suitable occasions, for the most note-worthy contribution to the knowledge of oil fields or to methods of producing oil.

A resolution was passed disapproving short course schools advertising to prepare men for work as petroleum geologists in a few months.

Resolutions of Appreciation

Whereas a large part of the great success of this meeting is due to the thorough hospitality and untiring efforts of the Chamber of Commerce, the members of the Oklahoma City Geological Society, and their wives.

Now therefore, be it resolved, that the association express its great appreciation and gratitude for the many kindnesses and courtesies extended, and that suitable copies of this resolution be sent to those mentioned above.

Respectfully submitted,
S. POWERS, *Chairman*.
F. H. LAHEE,
D. DONOGHUE,
Committee.

The following committees were appointed:

ASSOCIATE EDITORS

Ralph Arnold, Los Angeles, California, *Pacific Coast*.
J. H. Hance, Urbana, Illinois, *Central Western*.
K. C. Heald, Washington, D. C., *General*.
R. H. Johnson, Pittsburgh, Pennsylvania, *Appalachian*.
F. H. Lahee, Dallas, Texas, *South Mid-Continent*.
Sidney Powers, Tulsa, Oklahoma, *North Mid-Continent*.
Wallace E. Pratt, Houston, Texas, *Gulf Coast*.
J. P. D. Hull, Shreveport, Louisiana, *Louisiana*.

CONSTITUTION COMMITTEE

C. W. Washburne, New York, N. Y.; F. W. Clapp, New York, N. Y.;
W. E. Pratt, Houston, Texas; J. H. Gardner, Tulsa, Oklahoma.

MEMBERSHIP COMMITTEE

Ransom E. Somers, Pittsburgh, Pennsylvania, *Appalachian Division*.
Frank W. DeWolf, Urbana, Illinois, *Central Western Division*.
Richard Hughes, Tulsa, Oklahoma, *North Mid-Continent*.
Frederick H. Lahee, Dallas, Texas, *South Mid-Continent*.
Eugene Holman, Shreveport, Louisiana, *Gulf Coast Division*.
C. T. Lupton, Denver, Colorado, *Rocky Mountain Division*.
R. E. Collom, Berkeley, California, *Pacific Coast Division*.

ETHICS COMMITTEE

Roswell H. Johnson, Pittsburgh, Pennsylvania.
Alexander Deussen, Houston, Texas.
E. D. Nolan, San Francisco, California.

LEGISLATIVE COMMITTEE

Irving Perrine, Oklahoma City, Oklahoma.
D. W. Ohern, Oklahoma City, Oklahoma.
E. H. Sellards, Austin, Texas.

INTERNATIONAL RELATIONS COMMITTEE

A. C. Veatch, Port Washington, L. I., New York.
L. C. Donnelly, New York, N. Y.
Carl Beal, San Francisco, California.
The officers elected for the coming year are:
President, W. E. Wrather, Dallas, Texas.
Vice-President, Max W. Ball, Denver, Colorado.
Secretary-Treasurer, Charles E. Decker, Norman, Oklahoma.
Editor, Raymond C. Moore, Lawrence, Kansas.

These four together with George C. Matson, the retiring president, constitute the Executive Committee.

REPORT OF THE SECRETARY

Number of members March 15, 1919.....	210
Number of members March 18, 1920.....	392
Number of members March 15, 1921.....	621
Number of active members, March 8, 1922.....	631
Number of associate members March 8, 1922.....	136
Total number of members March 8, 1922.....	767
Applicants elected, dues still unpaid.....	36
Number of applications on hand.....	25
Number of members withdrawn.....	3
Number of members died.....	1
Number of members dropped, no clue to residence.....	2
Number of members dropped, non-payment of dues, 2 years.....	7
Full members in arrears 1921 dues	24

Associate members in arrears 1921 dues.....	8
Full members in arrears 1922 dues.....	232
Associate members in arrears 1922 dues.....	61
Total members in arrears 1922 dues.....	293

Respectfully submitted,
CHARLES E. DECKER,
Secretary.

**AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
REPORT OF TREASURER**

March 10, 1922

Balance in bank March 17, 1921			\$3,582.41
Received at Tulsa, from smoker and banquet			1,070.54
Receipts from annual dues			
Associates 1920	Active \$	50.00	
Associates 1921 \$462.00	Active	2,302.00	
Associates 1922 440.00	Active	3,918.61	
	\$902.00	\$6,270.61	
Total receipts from dues			7,172.61
Receipts from sale of bulletins			
Volume I 1917	\$234.25		
Volume II 1918	228.25		
Volume III 1919	367.35		
Volume IV 1920	530.50		
Volume V 1921	612.90		
Volume VI 1922	471.59		
Total receipts from sale of bulletins			2,444.84
Receipts from separates			105.09
Interest on money in savings account			97.41
Unclassified receipts			33.35
Total receipts from all sources			14,596.25
Disbursements			
Expense of Tulsa meeting			
Badges	\$	27.53	
Programs		18.50	
Reporter		35.00	
Smoker		171.00	
Dinner		825.00	
Local Bill		100	
			1,177.03
Cost of Bulletins			
Printing (Parts I-IV)	\$2,931.99		
Engraving		561.20	
Mailing		111.03	3,604.22

Salaries		
Editor	\$600.00	
Secretary-Treasurer	600.00	
Stenographers	267.60	
Mailing assistant	5.50	1,473.10
Supplies and printing (typewriter, filing case, etc.)		473.92
Postage		200.00
Cost of separates		153.63
Protested checks		63.00
Badges for Oklahoma City meeting		27.51
Drayage, express and freight		24.61
Exchange and refunds		7.80
Telephone and telegraph messages		5.01
Total disbursements		\$7,214.83
Balance in savings account		5,597.41
Balance in open account		1,733.54
		\$14,545.78
Outstanding checks		39.55
		\$14,506.25

Respectfully submitted,
 CHARLES E. DECKER,
Treasurer.

ELECTION OF OFFICERS

The following quotations from the address, on January 10th, of J. E. Spurr, retiring president of the Mining and Metallurgical Society, may be of interest to those considering the organization of the Association.

"The constitution of the Mining and Metallurgical Society as drafted was a very democratic one. It provided that all official ballots for officers should contain not fewer than two names; and that these names should be determined by a direct primary vote of all the members, giving the Council the right of nomination only when the primary vote did not result in as many as 11 votes for any executive office or in seven votes for a councillor. This was in contrast with the methods of the Institute, where there existed, and still exists, the practice of putting only one candidate for each important office on the official ballot, which is sent to each member with the grave request to vote for one out of one; where the succession of dynasty is determined by a very small and more or less permanent group; and where the membership at large has no direct vote in any matter of importance,—where, in other words, the form of government is that of a self-perpetuating oligarchy. Although provision is made for an alternative ticket at the instance of a certain number of members, such a rump ticket is rarely put in the field, which is a pity

when it is considered how largely this contributes to the joy of living, as in the well-remembered real election contest of Moore vs. Jennings.

* * * *

"The founders of the Mining and Metallurgical Society went further in their democratic constitution and provided that the council should be subject at any time to a test vote of confidence by the members, on request of 20 per cent of the membership, or two-fifths of the Council; and that in case of an adverse vote the whole Council should resign, and give way to a newly elected body. This part of the law has never been appealed to, but it puts the whole conduct of the Society in the hands of the members at any time they may choose to exercise the control.

"The constitution also provided that the Society could take no action on any matter of policy, except by a referendum or popular vote of its members, and this principle has been rigidly adhered to."

New York,
March 21, 1922.

CHESTER W. WASHBURN.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This publication does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to Charles E. Decker, Norman, Oklahoma.

(Names of sponsors are placed beneath the name of each applicant.)
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AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

LOUIS A. BARTON, of Ohio, was in Shreveport, in April, looking over Louisiana oil fields.

DONALD F. MACDONALD who returned to New York City a few months ago after almost a year in Mexico, visited Shreveport, Louisiana, and the nearby oil fields in April and has returned to New York.

HAROLD K. SHEARER was doing field work in Southern Louisiana during March and April. He has traveled considerably in Mexico and Central America the past two years.

J. M. DALE, who has been making subsurface geological maps for the Prairie Oil & Gas Co., is now with the Oklahoma Central Oil Co.

D'ARCY M. CASHIN, of the Humble Oil & Refining Co., is on the Isthmus of Tehuantepec.

JULIUS SEGALL is geologist for the ElOro Mining Co., with headquarters at Mexico City.

REVUE DE GEOLOGIE is a review of geological publications printed in English and French at the University of Liege, Liege, Belgium. The subscription price is 50 francs a year.

J. WALLACE BOSTICK has been appointed general manager of the Kansas & Gulf Co., with headquarters in the Petroleum Bldg., Tulsa.

R. W. CUMMINS represents the White Eagle Oil & Ref. Co., of Okmulgee, Oklahoma.

THE PAN-AMERICAN GEOLOGIST is a new monthly journal devoted to speculative geology, constructive geological criticism, and geological record. It is published by the Geological Publishing Co., Des Moines, Iowa, and is edited by C. R. Keyes. Subscription price it \$2.50 per volume and there are two volumes a year.

CARL D. SMITH located the well of Gillett et al in sec. 36, T. 20 N., R. 8 E., Pawnee Co., Okla., which is reported to be good for 1,000 barrels a day in the Wilcox sand at a depth of about 2,950 feet.

W. Z. MILLER, formerly with the Gypsy Oil Co., has gone into partnership with Mr. Carl D. Smith with an office at 447 Kennedy Bldg., Tulsa, Oklahoma.

C. J. HARES, chief geologist of the Ohio Oil Co., is a frequent visitor at Shreveport, La.

J. ELMER THOMAS has been appointed advertising manager for this bulletin.

The third annual meeting of the **SOUTHWESTERN GEOLOGICAL SOCIETY** will be held in Dallas, Texas, September 15-16th. The announcement reads: "It has been decided to have as the central idea of the program 'the geological problems of the Southwest' in which some of the larger problems of the region will be discussed. This will involve papers of economic as well as of purely scientific phases of the subject. It is suggested, however, that problems pertaining peculiarly to petroleum be omitted. Aside from this one feature the program will include everything from paleontology to potash, physiography, or ground water." Dr. J. W. Beede, of the Bureau of Economic Geology, Austin, Texas, is chairman of the program committee and R. B. Whitehead, 310 American Exchange National Bank Building, Dallas Texas, treasurer.

BRYAN HENDON is with the Standard Oil Co., of New Jersey and has headquarters at 82 Champs Elysee, Paris.

E. M. CLOSUIT is division geologist for the Gulf Production Co., at Wichita Falls, Texas.

REESE F. ROGERS is geologist for the Texas Co., at Shreveport, La.

GRADY KIRBY and **CARL PROBST** are working out of the Shreveport office of the Gulf Refining Co.

W. C. EYL, 407 City National Bank Bldg., Lexington, Ky., is publishing a new state map of Kentucky which is far better than any existing map.

JOHN W. TAYLOR is in charge of the geological work of the Gulf Production Co., in the San Antonio district, Texas.

DILWORTH S. HAGER, of the Gulf Production Co., now has headquarters at Houston, Texas.

CARL W. CLARKE has resigned from the Amerada Petroleum Corporation to enter consulting work at Okmulgee, Okla.

"Life of James Hall," is the title of a new book by **DR. JOHN M. CLARKE**, which may be purchased from S. C. Bishop, 2 High St., Albany, N. Y., at a cost of \$3.70 net. It is heartily recommended as a biography which should be read by all geologists.

CLIFTON M. KEELER, who has been appointed a valuation engineer in the oil and gas section of the Income Tax Unit, with headquarters at the Interior Building, Washington, D. C., recently spent some time in Oklahoma on business connected with the Unit.

JOHN CULLEN is assistant valuation engineer in the oil and gas section of the Income Tax Unit, and is stationed at Washington, D. C. His address is 3156 18th Street, N. W.

HENRY A. LEY has resigned his position with the Sun Company at Dallas, Texas, effective May 15, to become chief geologist for the Southwestern Gas Company of Independence, Kansas.

THE OKMULGEE GEOLOGICAL SOCIETY has elected the following officers for the coming year: LOUIS ROARK, *President*, C. A. WARNER, *Vice President*, and H. A. CLARK, *Secretary-Treasurer*.

C. W. TOMLINSON has discovered a new Ordovician hill in Southern Oklahoma in the midst of the area covered by dozens of geologists. This is an even greater accomplishment than the discovery of an oil field.

C. M. BAUER, W. B. EMERY and L. P. ANDRESEN are mapping the Kelvin area in Montana where a new oil field has been opened.

THE LAWTON, DUNCAN, and ARDMORE sections of the Southwestern Geological Society have combined at Ardmore and W. E. Hubbard, J. G. Bartram and Frank Gouin are directing the activities of the section.

D. R. SEMMES, of Tampico, has been in New York City.

WARNER NEWBY is with the Comar Oil Company at Ponca City.

HERBERT SHELTON has left the Buckley interests and is engaged in consulting work at Laredo, Texas.

L. J. YOUNGS is now with the Cosden Oil & Gas Company, at Tulsa.

D. W. WILLIAMS is doing consulting geology at Lawrence, Kansas.

L. G. KEPPLER, formerly with the Carter Oil Company, is with the Southwestern Oil Company at Tulsa, Oklahoma.

W. ARMSTRONG PRICE, formerly with the Transcontinental Oil Company of Mexico, is now with the Humphreys Petroleum Company, at Dallas, Texas.

R. F. BAKER has now become one of the immortals with *Quisque bakeri* named for him by Prof. David Starr Jordan. This imposing name is borne by a Miocene Fish 1- $\frac{3}{4}$ inches long, from a depth of 3,098 ft., at West Columbia, Texas.

G. JEFFREYS is in charge of the developments for the La Pryor Oil & Gas Company, at La Pryor, Texas.

C. L. BAKER has returned from South America and will spend the summer in Texas with the Bureau of Economic Geology.

A. T. WRIGHT is now with the Douglas Oil Company, at Pawhuska, Oklahoma.

W. P. HAYNES is in Roumania.

ED BLOESCH is spending the summer in Switzerland.

J. B. KERR, formerly with the Bureau of Mines, is now with the Carter Oil Company, at Tulsa, Okla.

E. V. WHITWELL and A. G. OLIPHANT are now engaged in consulting geology with offices in the Mayo Bldg., Tulsa, Okla.

E. F. SHEA is now with the Bradstreet Oil Company.

W. W. HENRY is now Treasurer of the Henry Oil Company of Tulsa, Oklahoma.

FRITZ AURIN is in Mexico.

L. G. WELSH, formerly with the Transcontinental Oil Company, has opened an office as Consulting Geologist in the Atco Building, Tulsa, Okla.

DEAN WINCHESTER, who was recently reported in these columns as working for the Standard Oil Company of New Jersey in Brazil, has returned to the United States, and has opened an office as Consulting Geologist, specializing in petroleum and oil shale. His address is 607 E. & C. Bldg., Denver, Colo.

A. E. FATH will spend the summer in Europe.

A. G. MADDREN is in the Argentine Republic for the Carter Oil Company.

C. W. WASHBURNE has moved his office to 2 Rector Street, New York.

R. T. HILL and R. D. GOODRICH have formed a partnership to engage in consulting work with their office in the Magnolia Building, Dallas, Texas.

F. W. GARNJOST is associated with J. G. White & Co., 37 Wall Street, New York City.

H. H. MCKEE and A. D. BROKAW have been engaged in special work at Mexia, Texas.

THE U. S. COAST and GEODETIC SURVEY in cooperation with the United States Geological Survey will establish several gravity stations in Kansas, Oklahoma and Texas during the summer.

D. C. BARTON has made a brief trip to Europe.

HARVE LOOMIS is working in Northern Mexico.

THE UNITED STATES BUREAU OF MINES is mapping Teapot Dome, Wyoming.

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Florence	Louisiana	Drumright	Kane	Mannington
	Oil City	Duncan	Oil City	Parkersburg
Illinois	Shreveport	Garber	Washington	Sistersville
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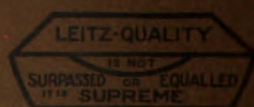
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VOLUME 6

NUMBER 4

BULLETIN
OF THE
AMERICAN ASSOCIATION
OF
PETROLEUM GEOLOGISTS

RAYMOND C. MOORE,
Editor

JULY-AUGUST, 1922
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NUMBER 4

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RAYMOND C. MOORE

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JULY—AUGUST, 1922

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THE BULLETIN is the official publication of the Association, and it is to be published in six numbers with a subscription price of \$5.00 per year. Extra postage on annual subscriptions is 30 cents for Canada and 53 cents for all other foreign countries to which postage is more than the local amount. Communications for the Editor and manuscripts should be addressed to R. C. Moore, Lawrence, Kansas. Remittances and business correspondence should be sent to C. E. Decker, Norman, Okla. Correspondence regarding advertisements should be addressed to J. Elmer Thomas, 751 First Nat'l Bank Bldg., Chicago, Ill.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

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†Vol. II	4.00	Vol. V	10.00
†Vol. III	5.00	‡Vol V, separate number, each.....	2.00
Vol. IV	7.50	Vol. VI	10.00
		Vol. VI, separate numbers each.....	2.00

*A few cloth bound copies of Volumes II and III are available at \$1.00 additional.

†Only a few copies of Volumes I and II are still available.

‡Except No. 2, double size number, \$3.50.

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CONTENTS

Natural Coal Tar Mistaken for Oil Residue	293
By GEORGE C. MARTIN	

New Oil Fields of the Los Angeles Basin	303
By RALPH ARNOLD and WAYNE LOEL	

Remarks on Surface Contouring.....	317
By EDWARD BLOESCH	

The Midway Limestone of Northeast Texas	323
By WALLACE C. THOMPSON	

Organic Material of Carbonaceous Shales.....	333
By COLIN C. RAE	

A Preliminary Study on the Recovery of Oil by Sinking Shafts and Driving Galleries.....	342
By LOUIS FRANKLIN	

EDITORIAL	348
-----------------	-----

GEOLOGICAL NOTES

Wildcat Oil Exploration in South-Central Arkansas, W. W. RUBEY	350
El Dorado Oil Field in Arkansas not on an Anticline, K. C. HEALD and W. W. RUBEY.....	358
The Fox Oil and Gas Field, WILLIS STORM.....	367
Oil "Showing" in Granite Explained, K. C. HEALD.....	369
Properties of Typical Crude Oils from the Producing Fields of Kansas, E. W. DEAN, M. B. COOK and A. D. BAUER.....	370
The Haynesville, Louisiana, Field, L. P. TEAS.....	371
A Method of Distinguishing Fused Cores, CLARENCE S. ROSS....	372
Oil in Middle Ordovician, K. C. HEALD.....	374
Is the Stapleton Pay of the El Dorado Field, Butler County, Kansas, Ordovician or Mississippian in Age? A. E. FATH	374
Oil Well in Scotland, SIDNEY POWERS.....	376

Bull. Am. Assn. Petrol. Geol.

DISCUSSION

The Necessity for Engineering in Developing Oil and Gas Properties, BEN K. STROUD	377
Is it Injurious to Close In an Oil Well? K. C. HEALD.....	379

REVIEWS AND NEW PUBLICATIONS

Oil Prospecting in Michigan, R. A. SMITH.....	381
A Treatise on Petroleum, Sir Boverton Redwood, S. POWERS....	382
Mud Laden Fluid and Tables on Specific Gravities and Collapsing Pressures, BEN K. STROUD.....	382
Preliminary Report on Proposed Pipeline from Monroe Gas Field to New Orleans, BEN K. STROUD and F. T. PAYNE...	383

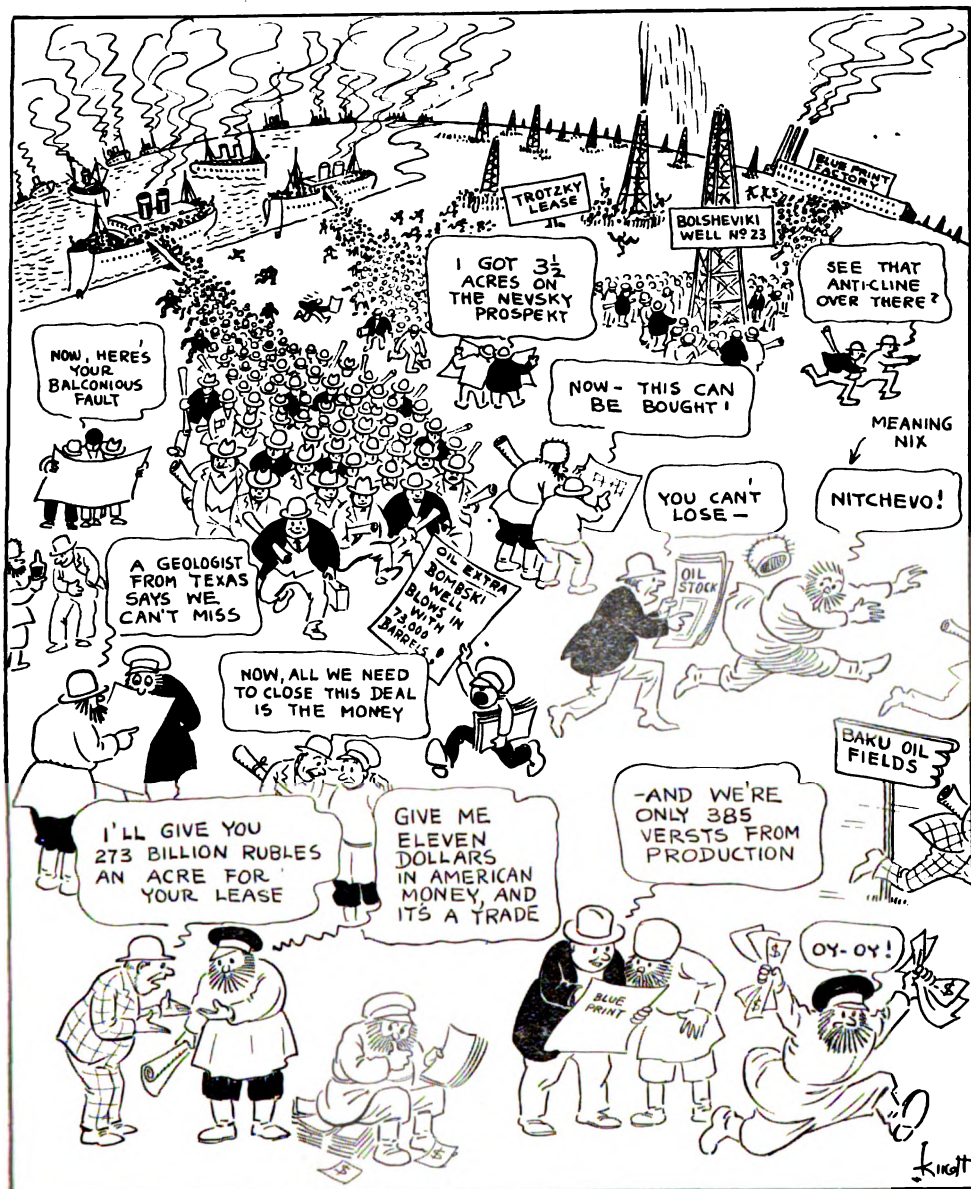
THE ASSOCIATION ROUND TABLE

Professional Ethics, F. W. DEWOLF.....	392
--	-----

AT HOME AND ABROAD

Current News and Personal Items of the Profession.....	394
--	-----

"ATTENTION LEASE HOUNDS! RUSSIA IS GETTING A BIG PLAY!"



—Courtesy of the Dallas Morning News

**THE
MID-YEAR MEETING
OF THIS
ASSOCIATION
WILL BE HELD IN
DENVER
OCTOBER 26-28th
1922**

SEE DETAILS ON PAGE 348

BULLETIN
OF THE
AMERICAN ASSOCIATION
OF
PETROLEUM GEOLOGISTS

JULY—AUGUST, 1922

NATURAL COAL TAR MISTAKEN FOR OIL RESIDUE¹

BY GEORGE C. MARTIN

INTRODUCTION

The purpose of this paper is to discuss the possible mistaking of natural coal tar for petroleum residue, with special reference to a reported discovery of petroleum in the Nenana coal field, Alaska. Petroleum seepages and residues are generally and rightly regarded as among the most useful and reliable indications of oil. Although those who are not familiar with oil seepages sometimes mistake iron stains, mineral salts, and living organic slimes for them, it is generally considered that a true seepage is unmistakable. It is important therefore to describe a material which has some of the generally accepted characteristics of petroleum residue but which is believed to be something else. The reasons why there is believed to be no petroleum in the Nenana coal field will be given more fully in an official publication.² The present discussion calls special attention to the broader question of the possible general inadequacy of a commonly accepted class of evidence.

It was reported in the summer of 1920 that a petroleum

¹Published by permission of the Director of the U. S. Geological Survey.

²Martin, G. C., A supposed oil seepage in the Nenana coal field, Alaska: U. S. Geol. Survey Bull. 737 (in press).

seepage had been found³ in the vicinity of Healy Creek, near the south edge of Nenana coal field, Alaska. A sample of sand soaked with bituminous material that was supposed to be petroleum is said to have been subjected to tests in which oils bearing some resemblance to petroleum were extracted by solution. Much interest was aroused thereby and several applications were made for oil leases. The writer made a brief visit to the supposed seepage, where he found reason to suspect that the supposed petroleum residue really was a natural coal tar produced by the distillation of burning coal beds. Chemical tests made in the laboratory of the Geological Survey by E. Theodore Erickson tend to confirm this suspicion.

The reasons for believing that this material is not petroleum residue are:

No adequate original source of petroleum is known in the strata which outcrop at the supposed seepage or in the rocks which underlie them.

The structure is not favorable for the accumulation of oil in the vicinity or for its escape at this place.

If petroleum were escaping here it would almost certainly escape at many other places in the Nenana coal field where it would probably not have been overlooked.

The material differs in smell and composition from most petroleum and contains substances which are generally regarded as characteristic of coal tars.

An adequate source for natural coal tar is found in distillation from coal beds which are known to have burned at many places throughout the field and are believed to have burned at this very spot.

DESCRIPTION OF THE BITUMINOUS DEPOSIT

The locality in question is in Sec. 16, T. 12 S., R. 6 W., Fairbanks meridian, being on the east bank and about a mile above the mouth of Cripple Creek which flows northwest into Healy Creek, one of the larger eastern tributaries of Nenana River. It is just inside the southern border of the Nenana

³Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey, Bull. 719, p. 73, 1921.

coal field which is situated in the northern foothills of the Alaska Range, in the central part of Alaska.

The Nenana coal field⁴ contains a thick section of Tertiary (probably Eocene) coal-bearing rocks resting unconformably on igneous and highly metamorphic rocks and overlain by Quaternary gravels. The coal-bearing rocks are between 1,200 and 2,000 feet thick and consist of slightly consolidated sands, clays, and gravels with numerous beds of lignite, there being at least 12 lignite beds of workable thickness, six or more of them exceeding 20 feet, and several being 30 to 35 feet thick. No organic matter was seen, other than the lignite and the usual disseminated vegetable detritus in the adjacent sandstones.

The bituminous deposit, or supposed "oil seepage" is near the top of a steep bank, about 150 feet above the creek. The coal-bearing rocks do not clearly outcrop here, the exposure being of hillside wash mantled with gravel from a terrace on the top of the bank (see fig. 1). The gravel and talus are laid bare in a small area where the soil and vegetation have been swept away, partly by landslides and partly by the wind. Here the sand and soil are soaked with tarry and oily material, which looks and smells somewhat like petroleum, but the smell is somewhat different from that at any seepage which the writer has visited. Shallow trenches do not show any beds that are absolutely undisturbed, but show more of the bituminous material than on the natural surface. The oil or tar is possibly scattered throughout the exposed material, not uniformly. Small irregular masses of sand seem to be completely soaked and have about the appearance and consistency of the tarry sands that were formerly used for sidewalks. The smell is noticeable to one walking over the area and is said to have led to the discovery. The accompanying sketch (fig. 1) shows the relation of the bituminous deposit to the gravels and underlying lignite-bearing beds. This sketch is a copy of a rough diagram furnished by Mr. W. E. Dunkle, who is thoroughly familiar with the locality although he did not have his detailed notes at hand when he

⁴Martin, G. C., *The Nenana coal field, Alaska*: U. S. Geol. Survey, Bull. 664, 54 pp., 1919.

made the sketch. The sketch indicates conditions substantially in accord with the observations of the writer, and supplies evidence in support of the theory here set forth, although it was made by one who did not have that theory in mind. It

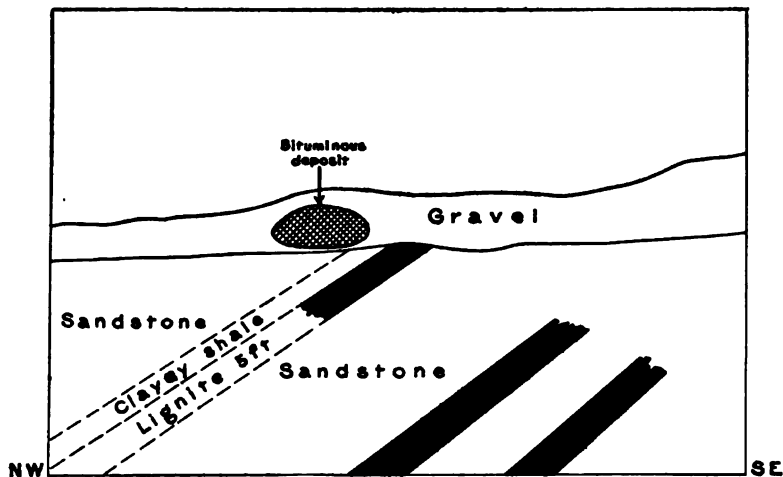


Fig. 1.

should be noted that the five-foot bed of lignite has its position merely indicated in the lower left corner of the sketch. This is where the writer saw no exposure of the lignite but only fragments of clinker indicating that a bed had burned. The upper part, only, of this bed is drawn solid in the sketch. This seems to indicate that the fire did not extend to the base of the gravel, but was probably drowned out a short distance below. The bituminous deposit is shown as lying wholly in the gravel, which is in accord with the belief of the writer, and it is situated directly above the place where the fire is believed to have died out. This is the very place where, in accordance with the theory here presented, the tars and oils would condense in greatest amount.

GEOLOGIC EVIDENCE THAT THE MATERIAL IS NOT PETROLEUM RESIDUE

The only sedimentary beds known near this place, or elsewhere in the Nenana coal field, which might be considered as a possible source of petroleum are the Tertiary lignite-

bearing beds. These are composed of slightly consolidated sands, gravels, and clays with many beds of lignite. Their organic constituents include only the lignite and the vegetable detritus which is common in sandstone associated with coal. The intervening strata are chiefly sands and gravels with no observable organic constituents. Clays are relatively few and thin, are probably less in amount than the lignite, and are light-colored and notably lacking in organic matter. Carbonaceous or bituminous clays or shales are relatively scarce, or wholly lacking. No beds of limestone, or of diatomaceous or infusorial earth, or any marine or brackish water beds are known. The strata, in brief, contain little or no organic matter from which petroleum might be derived unless it be the remains of the higher forms of vegetable life in, and associated with, the lignites, and these are not generally regarded as a likely source of petroleum. It may therefore be concluded that these lignite-bearing beds are not a possible source of petroleum.

The rocks exposed beneath the lignite-bearing beds include schists and intrusive igneous rocks, chiefly andesites and dacites. It is hopeless to look to these rocks for a source of oil. Moreover, at no place in this region are any rocks known which might be considered as probably oil-bearing. The northern foothills of the Alaska Range are well known geologically for a hundred miles or more both east and west of this locality, and throughout this whole belt the rocks under the Tertiary lignite-bearing beds are chiefly crystalline. It should be noted that there are some relatively unaltered Devonian limestones and Ordovician shales on the north flank of the Alaskan Range, but they have not been seen near this locality and are known only in the high mountains and not in the foothills. The marine Jurassic and Tertiary rocks which contain the known petroleum of Alaska have not been found north of the Alaska Range, except in the Arctic coastal province, and are believed never to have been laid down there.

GEOLOGIC EVIDENCE THAT THE MATERIAL IS TAR

The belief that this material is a natural coal tar produced by distillation from burning coal beds finds support in the

fact that coal beds have burned at many places throughout the field and have probably burned at this very spot. This is, moreover, one of the places where geologic conditions are especially favorable for trapping and condensing the liquids and gases which must be given off whenever a coal bed is burned.

The lignite beds through the entire Nenana field have been extensively burned from unknown natural causes. The burning began at an unknown date, in some places certainly before the deposition of the Quaternary gravels, and some beds are burning now. Although no burned coal beds were seen at the bituminous deposit, the coal beds and imbedding strata not being actually exposed there, abundant fragments of burned clay and masses of slaggy material resulting from the melting of the rocks, were seen in the soil below the deposit. It may, therefore, be assumed that coal has burned at this very place. There is no proof as to when the coal burned here. This fire is not burning now, but the fact that volatile material still remains in the bituminous deposit perhaps shows that the burning was comparatively recent.

It is evident that whenever a coal bed is burning there will be distillation of liquid and gaseous hydrocarbons in advance of the actual combustion. When the coal is heated liquids and gases will be driven off just as they are in making coke or in the artificial distillation of tars and oils from coal and lignite. These liquids and gases will, for the most part, burn or escape into the air but part of them will migrate through the rocks and if they reach cool or damp places they will undoubtedly condense there. The gases given off near the edges of the burned areas are the more likely to escape combustion. If the edge of the burned area approaches, without actually reaching, the surface of the ground the gases are likely neither to burn nor escape, but will in part condense in the damp cool soil.

The special condition favorable for trapping and condensation of distillation products at this locality is the presence of a nearly flat bench of Quaternary gravels lying unconformably across the beveled edges of the Tertiary lignite beds. (See Fig. 1). The surface of this bench, if it is like

the similar nearby benches, is dotted with marshy areas and pools of water. The materials composing the bench are doubtless either wet or frozen. A fire in the lignite would probably approach, without reaching, the base of the gravels. The gases and liquids given off from the burning and distillation would be trapped under the wet or frozen gravels and would in part condense there.

The natural burning of coal beds is well-known, but the published descriptions deal with the destructive effects on the coal beds and with the fusion of the overlying rocks, with no reference, as far as the writer knows, to the condensation products from the distillation of the coal. The reason for this omission is believed to be that, in most regions, the coal burns vigorously to the very outcrop so that, the distillation products either burn or escape into the air at the places where they might otherwise be most easily seen. The gases given off at great depths will, mostly, be diffused through buried rocks where their condensation products can not be seen till these buried rocks are laid open by natural or artificial excavation. The fact that natural tars have not been generally noted may also be due to the general lack of a wet or frozen cover. Generally either the rocks are wet to great depths in which case the coal does not burn, or else they are dry to the very surface, in which case they heat to the surface and the gases escape.

CHEMICAL TESTS

In order to obtain evidence as to whether the organic matter in the supposed seepage was actually derived from distillation of coal, samples have been studied by E. Theodore Erickson in the chemical laboratory of the Geological Survey. The following report was submitted on three samples collected by the writer, all from the same locality. Sample A is a selected sample made up of numerous small samples of the more bituminous black sand. Samples B and C are representative selections of the less bituminous (average) finer and coarser material:

Sample A: A chloroform extract indicated a small part of bitumen together with considerable soluble sulphur. The bitumen when heated with alkali solution and likewise the sample when so directly treated,

yielded strong odors of the pyridine series of compounds. Red litmus paper in the emitting odors readily turned blue. The intensity of these results are sufficient to estimate a considerable amount of these substances to be present in the comparatively small amount of bitumen in the sample.

Phenol like compounds were detected by the following procedures. The sample was treated directly with strong boiling alkali solution. The alkali extract after filtration from insoluble matter was acidified with HCl, boiled gently and a second filtration made. The final filtrate was colored reddish with organic matter, an ether extract was made, and upon evaporation of the ether a small amount of reddish organic matter remained. It possessed a phenol-like odor and when dissolved with a small amount of water the aqueous solution gave with dilute ferric chloride solution a positive reddish violet color. Pure phenol under the same conditions gave a bluish violet color. The phenol like residue when heated in the usual way with a small amount of two parts of H_2SO_4 and one part of HNO_3 gave the yellow color of the picric acid test. There were obtained the characteristic phenolic results of a moderately colored yellow solution in water, which deepened much upon the addition of ammonia. Phenolic compounds were detected in the phenol like residue by dissolving in 20 c. c. of normal NaOH solution and adding a small amount of diazobenzene chloride solution. A reddish color and precipitate were obtained identically as for small amounts of pure phenol. Under the same conditions negative results were obtained in a blank test and in a second blank test containing a small amount of pyridine.

There is also present some pyrobitumen or chloroform insoluble bitumen in the sample. A trace of arsenic and considerable free sulphur were detected.

A determination of the amount of soluble material in Sample A, using carbon disulphide as the solvent, showed 3.6 per cent of bitumen and 7 per cent of soluble sulphur. In this test carbon disulphide was used as the solvent, instead of chloroform, because it was found to yield a better separation of sulphur and bitumen upon evaporation.

Sample A was heated for 10 days at 105°C . when it showed a total loss of 10.42 per cent, which is believed to be chiefly moisture as considerable water and no observable oils condensed. The sample gave an odor of volatile substance both before and after the heating.

Sample B: A chloroform extract indicated a small amount of brittle bitumen. It gave pyridine and phenolic indications but not as intense as in Sample A. Free sulphur did not separate out from the chloroform evaporated extract as in Sample A. It contains practically no arsenic and a slight amount of pyrobitumen.

Sample C: The amount of bitumen obtained from Sample C was intermediate in amount between that of Samples A and B. The free sulphur obtained was less than in Sample A. The pyridine and phenolic indica-

tions are also intermediate between those of Samples A and B. There is present not over a trace of pyrobitumen and practically no arsenic.

The detecting of the pyridine series of compounds together with appreciable amounts of phenol like compounds in the organic matter in sample A may be considered as evidence that there are present coal tar products that have resulted from the destructive distillation of coal. To differentiate the bitumen from a natural petroleum bitumen and asphalt on these grounds becomes tenable when it is considered that petroleum in general contains small amounts of these substances especially the phenol like bodies. The diazobenzene chloride test is considered by Marcusson⁵ to give for natural asphalt and petroleum pitch a yellow or orange color and not the reddish colored results above which are obtained from lignite-tar pitch which contains phenol.

Loebell⁶ uses the diazobenzene chloride test to differentiate coal tar pitch from natural or petroleum asphalt, the latter giving negative results with this test.

Of the nitrogen constituents in petroleum it appears likely that allowance must be made for the presences of hydrochinolines other than the pyridine series of compounds as is evident in Maybery's work on the California petroleum.

It is understood that the samples here tested are directly connected with the natural combustion of coal, with which the results here reported align themselves.

Mr. Erickson shows above that the customary tests for distinguishing coal tar pitch from petroleum pitch or natural asphalt indicate that all three samples contain coal tar pitch. These tests are based on the presence in coal tar of certain compounds, notably phenol- and pyridine-like compounds, which are rare or lacking in most petroleum. The tests show that substances related to phenol and pyridine are present in comparatively large amounts and indicate that the material is a coal tar rather than a petroleum residue. The large quantity of sulphur is a further indication that the material was derived from burning coal, because although sulphur is a common constituent of petroleum, it usually occurs in only small quantities. Sulphur occurs also in all coals and lignites from which it would be easily volatilized and condensed, and is a common and troublesome constituent of the tars which are artificially distilled from lignites. The chemical tests might possibly be considered as not absolutely conclu-

⁵Holde, D., *The examination of hydrocarbon oils and saponifiable fats and waxes* (English translation by Edward Mueller) p. 222, 1915.

sive, since phenol and pyridine have been recognized in small amounts in a few petroleums, notably in some from California. Moreover, the writer would suggest that perhaps these substances may occur in larger quantities in petroleum residues than they do in live oils, but since Mr. Erickson's studies tend to confirm the conclusions drawn from the geologic field relations there is believed to be little doubt that this material is a natural coal tar and not a petroleum residue.

NEW OIL FIELDS OF THE LOS ANGELES BASIN, CALIFORNIA.

BY RALPH ARNOLD AND WAYNE LOEL.

INTRODUCTION.

The following paper has been prepared to meet a demand for a concise review of the recent developments in the oil fields surrounding the city of Los Angeles. It is based largely upon information gathered during the course of professional work within the last few years, and upon data secured by the senior author while engaged in investigations for the U. S. Geological Survey and for the U. S. Bureau of Mines. The figures used in the compilation of the curves were taken from the bulletin of the Standard Oil Company of California.

DEFINITION OF THE LOS ANGELES BASIN

The Los Angeles Basin may be defined as the area of low relief rising from the ocean on the west and shut in on the north by the Santa Monica Mountains, on the east by the Puente Hills and Santa Ann Mountains, and on the south by the San Joaquin Hills. Within these boundaries lies approximately five hundred square miles of territory, of which a small proportion is productive of petroleum.

LOCATION OF THE OIL FIELDS

The three principal producing areas of the Los Angeles Basin are:

- (1) The Los Angeles group or district including in order from west to east the Beverly Hills field, the Salt Lake field and the Los Angeles City field,
- (2) The Whittier-Fullerton or Puente Hills group, including Montebello, Whittier, Puente, Brea, Olinda, Kraemer, Richfield, Fullerton, Coyote, and the newly discovered field at Santa Fe Springs, and
- (3) the Beach group including Huntington Beach, Long Beach and Redondo.

Genetically speaking, the Beverly Hills field lies on the same structural line as the beach fields, but for all practical purposes it is best described with the Los Angeles fields.

The Montebello field, lying several miles east of the city of Los Angeles, constitutes the westernmost of the Whittier-Fullerton group. Development in this field has been extended in a southeastern direction, until the Montebello field almost merges with Whittier Heights. East of the Whittier field is a barren area three or four miles in extent, following which, in a southeasterly direction along the southern slope of the Puente Hills, is an unbroken succession of wells for several miles, known as the Brea-Olinda field. The old Puente field, the first to be developed in the Los Angeles basin, lies in the heart of the Puente Hills about a mile northwest of the Brea field.

The Kramer field, the easternmost extremity of the Los Angeles Basin area, lies in the mouth of the Santa Ana Canyon. Immediately west of Kraemer is the recently developed Richfield district, and northwest of the latter is a large group of wells designated as the Fullerton field. Almost merging with this group to the west are the wells in the Coyote Hills. Three to five miles northwest of the Coyote field lies the new territory surrounding Santa Fe Springs.

The Huntington Beach field, situated in the outskirts of the town of Huntington Beach, is one of the most recent developments in the Los Angeles Basin area, having been brought in practically within the year. Another of the recent fields lies on Signal Hill, in the northern part of the city of Long Beach and is known as the Long Beach field. A single well, about two miles east of Redondo, has been made to produce some oil, but owing to the condition of the hole at present its productivity is uncertain. This may be the nucleus of a new area of production which will be known as the Redondo field.

A little to the north of the Puente Hills and outside of the Los Angeles Basin some drilling has been undertaken on what is known as the Puente dome, situated a mile northeast of the town of Puente. While this does not fall within the basin proper, it should be considered as a part of the Los Angeles district and may become a small producing pool, although, to date, no actual production has been attained.

On the east side of the Puente Hills, midway between the

towns of Chino and Corona, two wells have shown some oil and give promise of a small field in this locality.

GEOLOGIC FORMATIONS

The principal formations involved in the geology of the

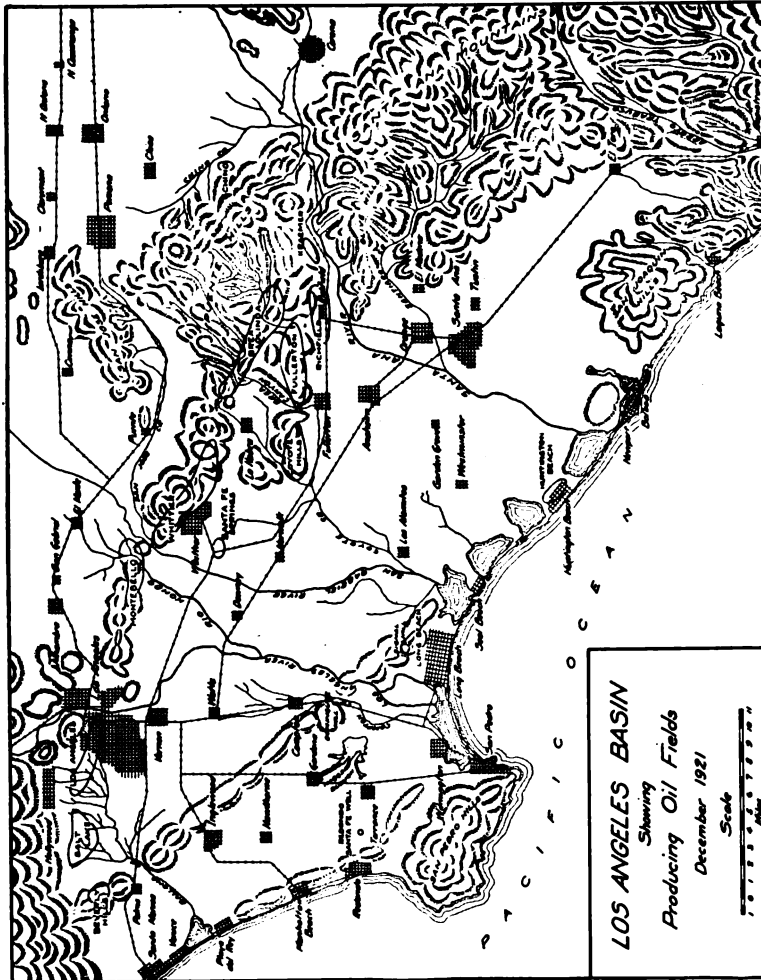


Figure 1.

Los Angeles Basin, in order of age beginning with the oldest, are: Jurassic or pre-Jurassic crystalline rocks; the Franciscan of probable late Jurassic age; the Chico of Cretaceous age; the Martinez and Tejon of Eocene age; the Sespe of

Oligocene age; the Vaqueros and the Puente of Lower Miocene age; the Fernando, which includes beds of Upper Miocene and Pliocene age; and the San Pedro and terrace gravels of Pleistocene age. The commercial quantities of oil are confined to the Miocene and Pliocene. The geologic column for the Los Angeles Basin district is shown in the accompanying tabulation.

Since the senior author's publication of the geology of the Los Angeles district in 1907¹ much detailed work has been done, which makes many refinements possible in the geologic column for Southern California. Since the results of later work have not yet been published, it is deemed inadvisable to incorporate at this time new ideas which might prove confusing without a suitable discussion of the reasons for the change, a thing impossible in a paper of this nature.

Period	System	Series	Los Angeles Basin Section	Thickness in feet
Cenozoic	Quaternary	Recent	Alluvium, Terrace-Gravels, San Pedro	1,000
		Pleistocene	— <i>Unconformity</i> —	
	Tertiary	Pliocene	Fernando	2,000 to 3,500
		Upper Miocene	— <i>Unconformity</i> —	
		Lower Miocene	Puente..... { Upper	300—2000
			{ Middle	300—2000
			{ Lower	2,000
			— <i>Unconformity</i> —	
			Vaqueros	1,000
			— <i>Unconformity</i> —	
		Oligocene	Sespe	2,200
			— <i>Unconformity</i> —	
Mesozoic	Cretaceous	Upper Cretaceous	Tejon	1,300
			— <i>Unconformity</i> —	
			Martinez	1,500
			— <i>Unconformity</i> —	
			Chico	2,500
	Jurassic		— <i>Unconformity</i> —	
			Franciscan	More 8,000

¹U. S. Geological Survey, Bull. 309, 1907.

A brief description of the principal divisions follows.

Basement Crystalline Complex.

Under this head are grouped granite, schistose and strongly metamorphosed crystalline rocks which make up the cores of many mountain ranges of Southern California, including those of the Santa Monica and Santa Ana mountains.

Cretaceous.

Chico. Of the Cretaceous only the upper part or rocks of Chico age are found in the Los Angeles Basin area. These occur principally in the Santa Ana and Santa Monica mountains and lie directly on the basement complex. They consist of hard sandstone with some thin-bedded, dark-colored shales, with a coarse conglomerate at the base. These rocks reach a maximum thickness of about 2500 feet and are not productive of oil in this part of the state.

Eocene.

Minor isolated outcrops of Eocene rocks occur in the Santa Ana mountains. The series is divided into two parts, the lower member being known as the Martinez, the upper as the Tejon.

Martinez. The Martinez is represented by a reddish-brown clay having a thickness of about 1500 feet.

Tejon. The Tejon is a buff, fine-grained sandstone having a thickness of 1300 feet.

The rocks of Eocene age are, like the Cretaceous, unproductive of petroleum in the region of the Los Angeles Basin.

Oligocene.

Sespe. Beds, approximately 2,200 feet in thickness, believed to be the equivalent of the Sespe formation of Ventura County, are found in the Santa Ana Mountains. The sands and shales in particular are usually brilliantly colored red, purple and green. No fossils are found in the formation and no oil, so far as known, has been found in it in this district.

Lower Miocene.

Vaqueros. The Lower Miocene of the Los Angeles Basin is divided into the Vaqueros and Puente formations. The former consists of sandstones, clay-shale and conglomerate.

The sandstone is usually gray or buff in color, with the shales darker or even purplish. Although there is no line of unconformity or other sharp line of distinction within the Sespe-Vaqueros series where exposed in this district, the upper 1000 feet are included in the Vaqueros, largely on lithologic grounds. The formation is fossiliferous, but non-oil bearing, except, possibly in the old Puente field north of Brea.

Puente. The Puente, or Monterey formation as it is known elsewhere in the state, is considered by far the most important as regards the source of petroleum, and in many instances the sandy strata in the upper part act as the reservoirs from which the oil is obtained.

In the Los Angeles Basin this formation is divided into three parts: a lower diatomaceous shale member, a middle zone composed principally of sandstones, and an upper division in which sandy and argillaceous foraminiferal shales containing considerable amounts of mica predominate over siliceous and diatomaceous shales.

Along the northeastern border of the basin the shales of the Puente are predominantly diatomaceous, but become more sandy to the south in the region of El Toro, the most marked line of transition being along Santa Ana River, this condition accounting for the lack of commercial deposits of oil south of this boundary.

The lower Puente shales reach a thickness of 2000 feet in the Puente Hills and may be in part of Vaqueros age. In the city of Los Angeles the relationship of this part of the formation to the underlying rocks is obscured by faults. The middle sandstone member varies in thickness from 300 feet in the eastern Puente Hills to more than 2000 feet in the vicinity of Los Angeles. The upper shale zone varies in a similar manner to the sandstone member and is approximately equal to it in thickness.

Upper Miocene-Pliocene.

Fernando. The early workers in Southern California geology placed all rocks later than the Puente in one series known as the Fernando formation. This was made necessary by reason of the fact that the separation of the beds on a litho-

logic or paleontologic basis was found to be extremely difficult and could not be undertaken with the meager data at hand. More careful investigations have shown that the Fern-

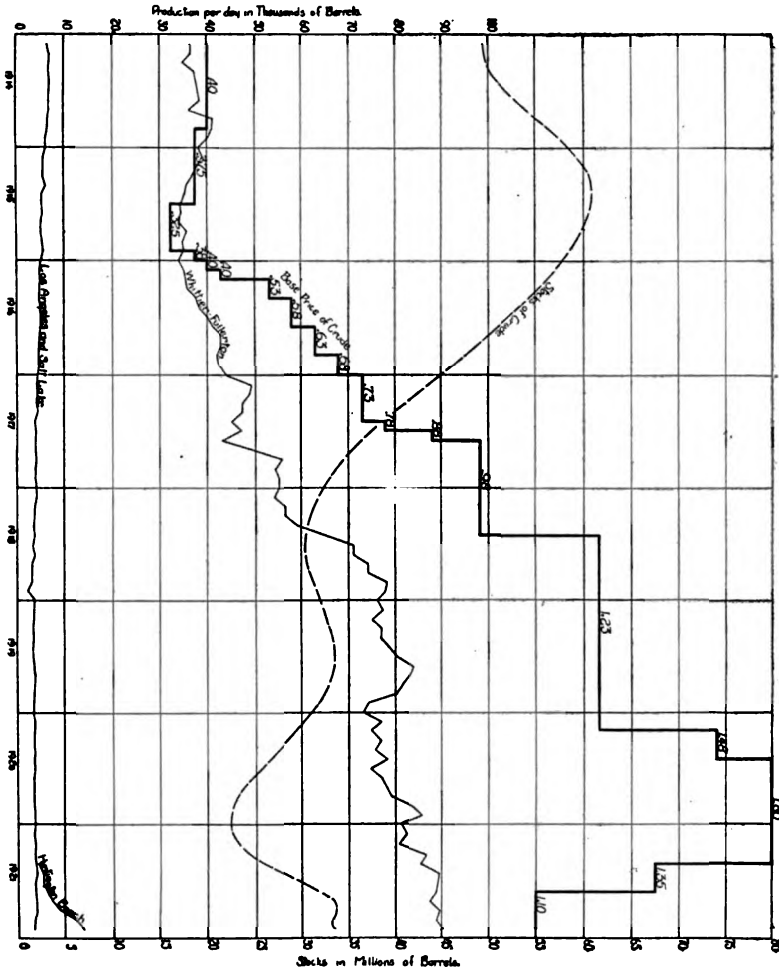


Figure 2. Production curves for the fields of the Los Angeles district, stocks for the state and base price for crude oil since 1913

ando may be divided into two parts—the lower being Upper Miocene in age, corresponding to the Santa Margarita formation of central California, while the upper portion lies in the Pliocene. Since the point of division has not been well

established south of the Santa Monica Mountains, the old inclusive usage of the formational name will be adhered to in this paper.

The basal portion of the Fernando is made up of blue and gray argillaceous shales and soft sandstones. These grade upward into conglomerates, soft gray shales, and gravels. The sandstone members of this series form many of the petroleum reservoirs in the southern portion of the state. The Fernando varies in thickness from 2000 to 3500 feet.

Recent-Pleistocene.

San Pedro-Terrace Gravels. The Pleistocene is represented by a series of gravels, loose sands and sandy clays, not distinguishable from the underlying Pliocene except on a paleontologic basis. An occasional heavy oil or tar sand is encountered in the lower beds of this series which reaches a maximum thickness of about 1000 feet.

GENERAL STRUCTURE

Broadly speaking, the axes of the major structural features of California parallel the coast line. This condition obtains in the Los Angeles Basin district with slight modifications. The uplift of the Santa Ana Mountains is the controlling structural feature on the east, while that of the Santa Monica Mountains forms the northern rim of the basin. The compressional forces from the west have been exerted upon rocks which lie beneath the ocean some distance from the shore and are evidenced only in a minor degree in the uplift of the San Pedro Hills.

Between the Santa Ana Mountains and the sea lies a broad synclinal valley the axis of which extends from the southwestern limits of the city of Los Angeles to the vicinity of El Toro. The western flank of this syncline rises to what is known as the Inglewood line of uplift, taking the form of an anticline with beds gently dipping to the east, but with a more steeply inclined western limb modified in places by faulting. This major line of folding extends in a southeasterly direction from the Beverly Hills field at the base of the Santa Monica Mountains on the north, through Dominguez Hill, Long Beach, and Huntington Beach, to the south.

Between the Inglewood uplift and the coast lies a second and much smaller syncline, the axis of which runs parallel to that of the uplift from a point midway between Santa Monica and Palms, through Nigger Slough and the city of Long Beach.

Between this syncline and the San Pedro Hills to the southwest a minor anticlinal condition may exist, but is only faintly suggested at the surface by the topography. The idea of such a condition is borne out, however, by the fact that the oil well east of Redondo has given evidence of being a commercial producer.

The compressional forces induced by the elevation of the Santa Monica Mountains formed a series of cross folds wherein accumulated the oil of the Los Angeles and Salt Lake fields.

The Puente Hills, which form the northeastern rim of the Los Angeles Basin, are the result of the same forces, diminished in intensity, which caused the rise of the Santa Ana Mountains. The direction of dominant stress was from the northeast, causing the beds along the southwest slope of the hills to be faulted and sharply tilted, producing a monoclinal condition in the Whittier and Brea fields. To the west the compressional forces were less intense, allowing the formation of a normal anticline in the Montebello field.

From the main uplift of the Puente Hills several minor folds branch off to the west. On these are situated the Kraemer, Richfield, Fullerton, Coyote Hills, and Santa Fe Springs fields.

DESCRIPTION OF NEW FIELDS

The older producing fields of the Los Angeles district have been in existence for so many years and are so widely known in detail that further discussion of them should not be entered into here. These fields are described in detail by Eldridge and Arnold in Bulletin 309, U. S. Geological Survey.

The four new fields—Richfield, Huntington Beach, Long Beach, and Santa Fe Springs—may be briefly described as follows:

Richfield. The Richfield district lies at the base of the Puente Hills in an area of low relief without marked topo-

graphic features which might indicate the presence of sub-surface structure.

The discovery well was brought in in the fall of 1919, at a depth of 2900 feet, with an initial production of 3000 barrels per day, which rapidly increased to double this amount. This well was quickly followed by others, varying in daily production from seventy-five to several thousand barrels. The producing wells now cover an area two and a half miles long by a mile wide.

The structural condition of the field is that of an anticline modified slightly by cross folding. The axis runs in a general east-west direction with the plunge to the west.

There are two producing zones, slightly unconformable, the upper of which is in the base of the Fernando, while the lower is probably in the upper part of the Puente. The stratigraphic distance between the oil horizons is approximately 1000 feet. The lower zone yields the best oil, although there is a considerable variation in gravity in both zones in different parts of the field.

The wells range in depth from 2700 feet to 4300 feet, while the gravity of the oil varies from 16° B. to 27° B. The average daily production per well is now in the neighborhood of 160 barrels.

Huntington Beach. The Huntington Beach field lies on the coast at the extreme southern end of the Inglewood line of uplift. A low hill near the center of the field is the only topographic feature which might indicate an anticlinal condition of the beds beneath.

The discovery well was brought in in the late summer of 1920, at a depth of 2700 feet, with an initial production of 1800 barrels per day. Immediately, a most intensive drilling campaign was started by innumerable small companies with holdings ranging from one city lot to several acres each, with the result that within a year over fifty wells were brought in. The average daily production per well at present is about 300 barrels. The proven territory now covers an area approximately three miles long by a little over a mile wide.

The structural condition of the field is that of an elongated dome, modified by several minor cross folds. The major axis

extends in a northwesterly-southeasterly direction, paralleling the coast line.

Two major zones of production exist—an upper, known locally as the Bolsa, and a lower, referred to as the Ashton. The producing horizons are separated stratigraphically by approximately 450 feet. A slight unconformity exists between these horizons, similar to that in the Richfield district, the Bolsa sand probably being in the Fernando formation while the Ashton horizon may lie in the top of the Puente. Formational correlation in this field is extremely difficult, owing to the great lithologic similarity existing between the beds of the two zones.

Very careful work is now being done by the larger companies in developing this field, and numerous core samples are being taken from drilling wells with the object of determining the structural conditions with greater exactness than has heretofore been deemed necessary. The detailed microscopic examinations now being made of the core samples are bringing to light new facts regarding underground conditions, resulting in many cases in greatly increased production.

The difference in the gravity of the oil produced from the two zones is quite marked, that of the lower zone running as high as 28° B. while the average gravity of the oil from the upper zone is only 20° B. The wells range in depth from 2000 feet to 4200 feet.

Long Beach. The wells of the Long Beach field lie on the slopes of Signal Hill, which rises to an elevation of 300 feet and is a part of the Inglewood uplift. No indication of subsurface structure is visible on Signal Hill except in the steeply tilted beds of Quaternary age.

The discovery well on Signal Hill was brought in during the latter part of June, 1921, at a depth of 3000 feet, with an initial flow of 1,000 barrels daily. At the present writing there are eight wells producing, but none so far has equalled the discovery well. The new wells have not been producing long enough to permit any conclusions regarding the future of the field. The proven territory at present would appear to cover an area approximately one and a half miles long by one-half mile wide.

The structural condition of the field is that of an anticline broken by both longitudinal and transverse faults, the magnitude of which cannot be determined until more wells have been drilled.

Two zones of production occur in this field, as in Huntington Beach, but the data concerning underground conditions are so meager at present as to render further discussion impossible. Owing to the complicated structural conditions brought about by faulting, the companies are carrying on development slowly and are using every precaution to determine the structure with great exactness. The oil ranges in gravity from about 18° to 25° Beaume. The wells now producing in the field vary in depth from 3000 feet to 3300 feet. Some deep wells are being drilled but have not as yet reached any producing sands.

Santa Fe Springs. The new field of Santa Fe Springs is located about two and a half miles southwest of Whittier.

Drilling in this vicinity has progressed for several years, a number of wells having been sunk to four and five thousand feet without encouraging results. The discovery well, a little south of the Santa Fe Springs station, was the first one to produce a sufficient quantity of oil to cause excitement. This well came in the last week in October, 1921, at a depth of 3780 feet, with an initial production of 2000 barrels per day of 31° B. oil. At the present writing this production has increased to 4000 barrels per day. A large number of wells are now being drilled in the vicinity, with the expectation that a field of considerable extent will be developed.

There is little surface evidence outside a low topographic ridge in the Santa Fe Springs area to serve as a guide in determining the structure, but from a consideration of the regional geology the axis of this field should lie in a northwesterly-southwesterly direction, and is probably a continuation of the Coyote Hills anticline.

PRESENT AND FUTURE PRODUCTION

Although the oil fields of the Los Angeles Basin are among the oldest in the state, the first producing well having been drilled in 1880, the peak of production has not yet been

reached. The discovery of new fields has kept pace with the increase in demand so successfully that, at the present writing, production exceeds consumption, with the result that oil has been going into storage rapidly since the beginning of 1921.

In Fig. 2 are shown the production curves for the fields of the Los Angeles district, together with the stocks for the state and the base price for crude since 1913.

The relationships of these curves are very interesting. The economic effect of the war is plainly shown. From the outbreak of hostilities in 1914, when our exports were shut off, until the summer of 1915, when the industrial conditions in this country had become readjusted, the stocks of crude rose to a peak of 62 million barrels with a corresponding drop in price to 32½ cents per barrel. From this time on until the end of the war it was impossible to keep production up to the demands of industry, with the consequence that stocks diminished rapidly and the price rose as never before in the history of the California industry.

The effect of these conditions was to stimulate drilling. The production of the Los Angeles-Salt Lake field could not be increased since it was already completely developed, but by the beginning of 1918 production in the Whittier-Fullerton district began to increase rapidly and wild-cat drilling was in progress everywhere. The increased drilling campaign had its effect in arresting the downward trend of the "Stocks Curve" during 1918 and the early part of 1919, but the new wells soon began to drop off in production, so that in the latter part of 1919 the stocks again began to dwindle rapidly, reaching a minimum of 22 million barrels in December, 1920. The price rose to its peak of \$1.60 per barrel in the summer of 1920, but has declined since in proportion to the increase in storage.

In the fall of 1919, the newly-discovered Richfield district began to add its oil to the Whittier-Fullerton production, once more starting the production curve for that field upward.

The sharp decline in the "Stocks Curve" during 1920 was partly due to the curtailing of production in the San Joaquin Valley fields during the oil workers strike.

The subsequent rise of the curve during 1921 was affected

not alone by the increased production in the Los Angeles district, but also by the bringing in of the Elk Hills field, in the San Joaquin Valley, in the fall of 1920.

Since the beginning of 1920 the Whittier-Fullerton curve has continued to rise, because of development of the Richfield district. If the Santa Fe Springs field approaches Richfield in productivity, the curve may not reach its peak for several years, while the new fields of Huntington Beach and Long Beach may keep up the production for the entire district for some time. However, it must be evident that the continual discovery of new fields can not go on indefinitely, and within the next few years the beginning of the final decline of the Los Angeles Basin fields will be at hand.

REMARKS ON SUBSURFACE CONTOURING

EDWARD BLOESCH

The geologists working in the Mid-Continent Field have found out the importance of subsurface structure, as it varies considerably from the surface structure on account of unconformities and changes in thickness of certain formations.

The best method to work out the subsurface structure in a territory of low structural features like the Mid-Continent Field is by way of structure contours on a certain horizon shown in well records. Such a horizon should be close to the probably producing zone, as the main use of a subsurface map is to predict oil or gas possibilities. It should not be separated from this zone by a marked unconformity. Quite often it is advisable to contour different subsurface horizons in the same area on account of the presence of a number of unconformities.

As a rule it is not an easy matter to pick out a proper horizon on which to base subsurface contours. It ought to be a formation of regular thickness, preferably thin, which extends over all the territory to be mapped. The best formations are generally thin limestones and coal beds. Unfortunately the drillers do not pay enough attention to these formations and many well logs do not contain them or do not show their thickness and depth accurately. Therefore it is often necessary to use sands which are known to be lenticular and of variable thickness. Quite often the top or the bottom of such a sand is used for contouring just as it is given in the log. A sand surface is not generally deposited on a level. The currents, which erode even locally, wash the sand into low wavy ridges. Furthermore the deposition of a massive sandstone does not terminate abruptly. In one place shale or sandy shale is deposited, while in another sand is still being washed in. Even where sand deposition is abruptly terminated by shale, sedimentation turns to sand again, chang-

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ing several times before the sediment is pure shale. In studying the sandstones of the Mid-Continent field at the surface, these minor ledges are often observed above the main sandstone. In doing surface work it is comparatively easy to tell on which ledge one is working. The average well records do not give these minor ledges separately. One driller will include them in the shale, while another one will put them and the intervening shale together with the main sand. Therefore a map contoured on a sand surface is not a structure map proper. The same is true of a map contoured on the base of a sand, but in a less degree, as the change in deposition from shale to sandstone is usually more abrupt than from sandstone to shale. The difference between such a sand surface map and a real structure map is negligible in a territory where the folding is fairly pronounced, as for instance in the Appalachian oil fields. In the Mid-Continent field with its low dips, however, where a contour interval of ten feet is customary, it is often important, as it may influence the conclusions drawn from the contour map. Therefore it is advisable to check the drillers records and to use in some logs, where the reported sand is of abnormal thickness a horizon within the sand, and in logs where the sand is evidently too thin, to use a horizon above the sand shown in the log. The proper horizon to be used in each log can be determined by comparing top and bottom of the sand and other formations of the log which are not separated by unconformities from the sand to be contoured.

In order to make this plain reference may be made to the accompanying Plate I, where five logs from sections 14 and 15 in T. 13 N., R. 15 E. in western Muskogee county, Oklahoma are plotted.

The only horizon which can be identified with certainty and which is reported in all the five logs is the "Glenn" sand or Salt sand of the drillers. The thickness of this sand varies so much in the well records, that neither the top nor the bottom can be used as recorded for structure contours. Suppose a structure contour map had to be drawn on top of the "Glenn" sand. Only in logs Nos. 2 and 4 the actual top of the sand designated by a coal bed could be used. In No. 5 an abnormal

T. 13.N - R. 15.E

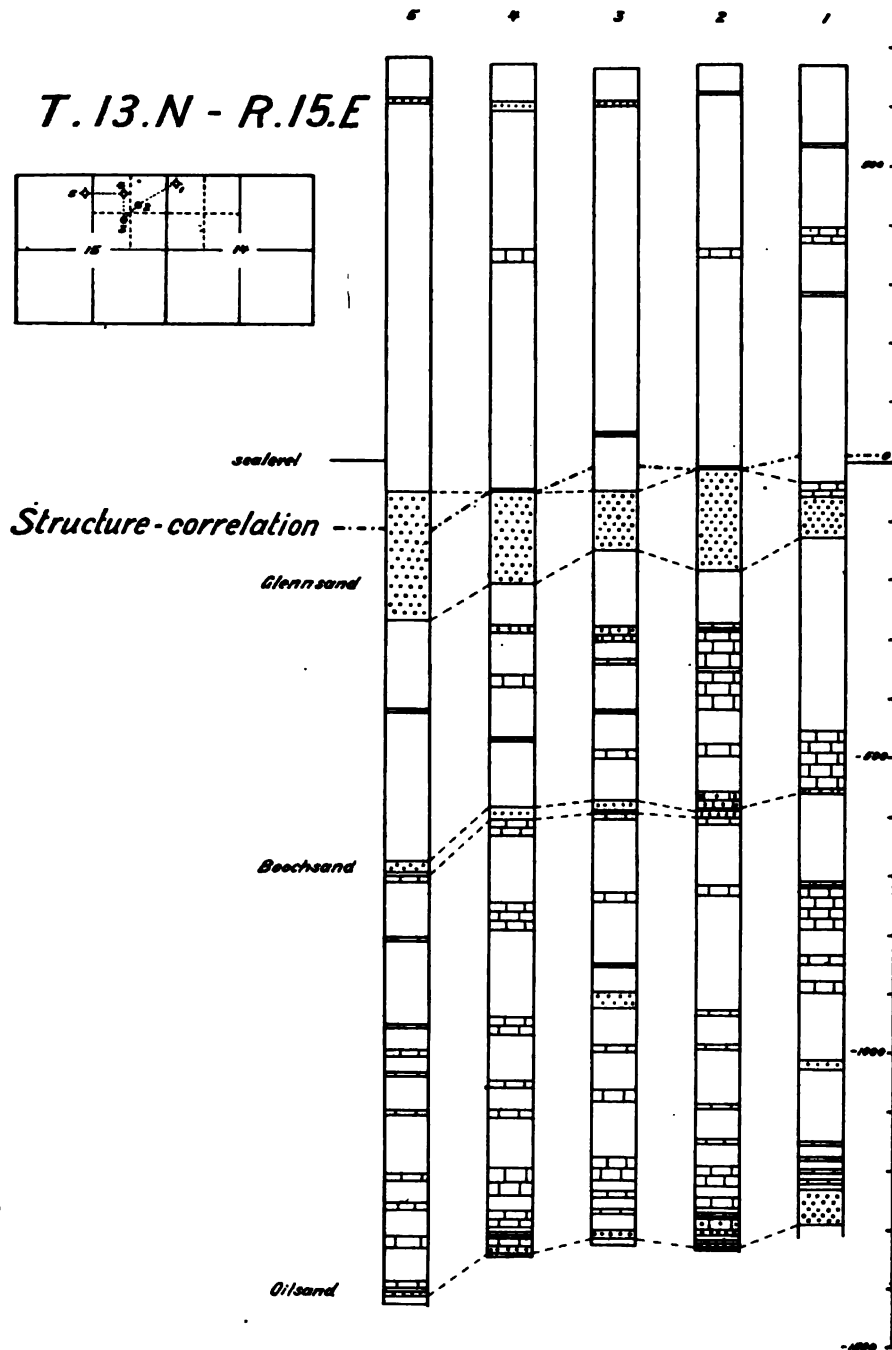
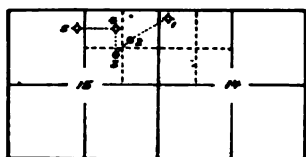


Plate I. Illustrating relation between sand surface and proper structure correlation.

sand thickness is given, so that a point below the top as shown on the plate should be used. In Nos. 1 and 3, where the sand is reported abnormally thin, the horizon above the sand should be taken. In order to determine these points, the bottom of the "Glenn" sand and other horizons, for instance the Booch sand have to be consulted. If the top of the "Glenn" sand as shown in the logs be used, it would give valuable information as to accumulation of oil and gas in the "Glenn" sand. But where conclusions on the structure of lower formations are to be drawn, the proper structural correlation as shown on the plate is much more valuable. As can be seen it runs almost parallel to the oil sand producing in this place.

Contours on a sand surface, even where they differ considerably from real structural contours, have a certain value in studying gas and oil accumulation or the water level in a particular sand and contours on the bottom of a sand are also important for such questions. For purely structural deductions, for instance the relation between surface and sub-surface structure or predictions on horizons below the contoured sand, real structure contours are more valuable.

Sand surface contours often show local irregularities, which have nothing to do with structure and only tend to cloud the general outline and real nature of the structure. One can almost tell by looking at some contour maps, that they represent a sand or erosional surface.

On Buttram's¹ structure map of the Cushing field the main part of the area is contoured on the Pawhuska limestone. Only in the vicinity of Drumright, where the Pawhuska is eroded, elevations of the Layton and Wheeler sands from well logs were used, figured on the Pawhuska using a constant interval. This part of the map has an entirely different character from the other one. Instead of major folds it shows a number of small, very irregular domes. The writer does not consider these features as structural. They are the irregularities of the sand surface as reported in the well logs.

Even the subsurface maps of the Cushing field by Beal²

¹Buttram, Frank, *The Cushing Oil and Gas Field, Oklahoma, Okla. Geol. Surv. Bull. 18, plate 1, 1914.*

²Beal, Carl H., *Geologic Structure in the Cushing Oil and Gas Field, Oklahoma, U. S. G. S. Bull. 658, plates 7, 8 and 9, 1917.*

on the Layton, Wheeler and Bartlesville sands with a contour interval of 25 feet show local irregularities, which reflect sand surface rather than structure. That this is the case is emphasized by the fact, that some of these local features of one sand surface are not indicated on the map of the deeper sands. The Layton sand in particular seems to have an irregular surface or it has not been properly interpreted by the drillers.

Fath³ in his recent bulletin on the Eldorado, Kansas, field discusses the influence of irregularities of the surface of the 660-foot sand on the structure contours of this sand.

A very interesting sand surface is shown by Berger⁴ in his "Subsurface Structure" map of the Sallyards field, Kansas, with contours on top of the Sallyards sand. This sand is lenticular and thins or even pinches out at the edge of the producing area. Therefore the bottom of the sand would show contours entirely different from the top. This sand surface is not real structure as horizons below and above (see surface structure) have a different configuration. While it governs the accumulation in the Sallyards sand, conclusions from this "Subsurface structure" on other deeper sands would be misleading. The Sallyards field may help to solve the question whether the domes and anticlines in the Mid-Continent Field have been formed by lateral compression or if they are due to differential settling. If the bottom of the Sallyards sand shows a relief similar to the surface structure or to the structure of a limestone not far above the sand, then differential settling had very little effect. On the other hand if there is no relation between sand bottom and the structure of the upper formations, it is a case of differential settling.

It may be necessary to contour on an erosional surface at the base of a slight angular unconformity. The contours on top of the Boone limestone in the Independence quadrangle⁵,

³Fath, A. E., *Geology of the Eldorado Oil and Gas Field, Butler County, Kansas*. State Geological Survey of Kansas Bull. 7, p. 77-79, 1921.

⁴Berger, Walter R., *The Relation between the Structure and Production in the Sallyards Field, Kansas*, Bull. Amer. Assn. Petroleum Geol. Vol. 5, No. 2, 1921.

⁵Schrader, F. C., U. S. G. S. Folio No. 159, Independence, Kansas, 1908.

Kansas, probably the first ones published in the Mid-Continent field, are of this nature. They do not represent actual structure but only an approximation to it. In subsurface work in or below the Mississippian it is almost impossible on account of the various unconformities to make a contour map which is absolutely sure to be a real structure map. We will be able to improve on this with better well records and better knowledge of the stratigraphy of these formations in the Mid-Continent field.

Fath^e gives a subsurface structure map of the Eldorado, Kansas, field contoured on top of the Stapleton oil zone. As he considers the top of this zone an erosional surface truncating several formations, his contours do not show the structure proper but the form of that surface. This probably accounts for the difficulty in explaining some of the oil development with his "structure" map. The "low upfolds and shallow depressions" on the Shumway dome are probably not structural features but are either due to inaccuracies of the drillers or to erosion on top of the Stapleton oil zone.

In doing subsurface work where it is important to contour real structure in territory of low dip it is not advisable to use the drillers interpretations, but an attempt should be made to eliminate not only the actual mistakes in the logs, but also irregularities of depositional or erosional nature. Where this is not possible or where it is the intention to depict a sand or erosional surface rather than structure, the fact should be mentioned, that the contours do not show the real structure, but only approximate it.

THE MIDWAY LIMESTONE OF NORTHEAST TEXAS

WALLACE C. THOMPSON

INTRODUCTION

The Midway formation, the basal member of the Tertiary system in the southern United States, outcrops in a narrow belt along the Gulf Coastal Plain from Georgia to Rio Grande River. It is exposed with certain interruptions in a belt from 5 to 15 miles wide across the state of Texas. Beginning on the Rio Grande south of Eagle Pass it extends eastward to the vicinity of San Antonio, where the strike takes a northeasterly direction which it follows as far north as Hopkins County. Here the strike changes again and the belt continues eastward into Arkansas, concealed in the extreme eastern part of Texas by the overlapping Wilcox formation.

It is hardly possible in the space of one paper to discuss thoroughly all of the different phases of interest mentioned herein since any one of several subjects which are only briefly mentioned might well be treated in a special paper. We shall be chiefly concerned with the basal portion of the Midway in the area from southern Limestone County northeastward through Texas, (Plate I), omitting as far as possible discussion of details in any locality. The basal limestone of the Midway formation is the only recognizable horizon in a large part of east Texas and is therefore of particular interest to petroleum geologists.

THE NAVARRO-MIDWAY CONTACT

Between the Midway and the underlying Cretaceous is an unconformity or, rather, a disconformity, which is in evidence all along the contact in the United States. Few if any points of contact show a marked or noticeable change in sedimentation, but paleontologic investigations show that a complete change in life took place between the latest Cretaceous and the earliest Tertiary deposits.

In southwest Texas the contact is well defined. At certain localities in the Rio Grande country the Midway limestone

rests directly upon beds of the Escondido formation, the equivalent of the upper Navarro. Farther along the outcrop, especially in east Texas, the contact is more obscure since basal sandstone and shales are present between the limestone members and the underlying Navarro formation. These beds are soft and weather easily making the contact hard to distinguish. Kennedy mentions two places where the Navarro-Midway contact is exposed, the first on the bank of Brazos River one mile above the Milam County line in Falls County¹, the second several miles west of Elmo in Kaufman County². In each case fossil evidence rather than a break in sedimentation is used to define the contact.

It is thought that the Midway sea advanced over a land of moderate relief or at least a topography devoid of any sharp features. The evidence at the contact suggests that the lower sands and shales of the Midway, which vary from 0-75 feet in thickness, filled in the depressions in this topography so that the limestone, which is younger, was deposited on a relatively flat surface. In some cases the thickening of the limestone may be due to its having been deposited in such depressions. The limestone sometimes rests directly upon Cretaceous rocks but is more often underlain by a varying thickness of Midway beds.

It seems very probable that a large part of the basal Midway was derived from the clay and sand of the Navarro upon which it was laid down. Naturally the contact of two such similar sets of beds is very hard to distinguish although it represents a great time interval.

THE MIDWAY LIMESTONE IN ITS BELT OF OUTCROP

While the basal part of the Midway formation may be traced for a great distance across the state there are numerous changes in its character to be noted at different localities.

From Falls County northward through Limestone County

¹ Kennedy, Wm. The Eocene Tertiary east of the Brazos River. Proc. Acad. Nat. Sci. Philadelphia, 1895 p. 145.

² Kennedy, Wm. A section from Terrell, Kaufman Co., to Sabine Pass on the Gulf of Mexico. Third Ann. Report Geog. Survey of Texas 1892 p. 49.

to the quarry west of Richland, in Navarro County, the limestone is fairly continuous and does not change in character materially. The outcrop is characterized by sharp cuestas capped by the limestone, which in this district consists of several irregularly stratified beds, light yellow to white in color, and aggregating 20 to 50 feet in thickness.

The thickness of the limestone increases locally south of the Mexia field. In several wells drilled in southern Limestone and northern Falls counties, as much as 200 feet of almost unbroken limestone is encountered³. This thickness evidently represents a local condition in sedimentation since at no other point, either north or south, is the limestone as thick as this. While faults are known to exist in this area the structure has been worked with sufficient care to show that the thickening of the limestone is not due to repetition of beds.⁴

The following section measured at the Old Reunion Grounds south of Mexia, is characteristic of a large part of the Mexia district⁵.

Section of Midway limestone south of Mexia, Texas

White fossiliferous limestone weathering into irregular blocks.	3 feet
Covered.	8 feet
White fossiliferous limestone, well stratified.	11 feet
Covered.	14 feet
Hard resistant, blue gray limestone.	5 feet

The limestone outcrops in the Mexia district in two parallel belts extending in a northeast-southwest direction, one through the Mexia field and the other to the west along the ridge which passes through the town of Tehuacana. These belts are separated in the Mexia field by a downthrown block or a graben the throw of which is about 400 feet.

Between Richland Creek and a point north of Kemp in Kaufman County, the limestone series is not seen. Other members of the Midway are present throughout this distance but the fossiliferous basal members do not appear. A concretionary bed of chert and cherty limestone crosses Trinity River about

³ Three wells drilled by the Atlantic O. Prod. Co. namely the Steele in Falls Co., and the Garrett and Ainsworth in Limestone County, passed through a thickness of limestone from 150-200 ft.

⁴ Whitehead, R. B. Personal communication.

⁵ Measured by Willis Storm.

2 miles northwest of Bazette Crossing in Navarro County. This is the only hard bed that can be traced across the river and is considerably above the limestone stratigraphically.

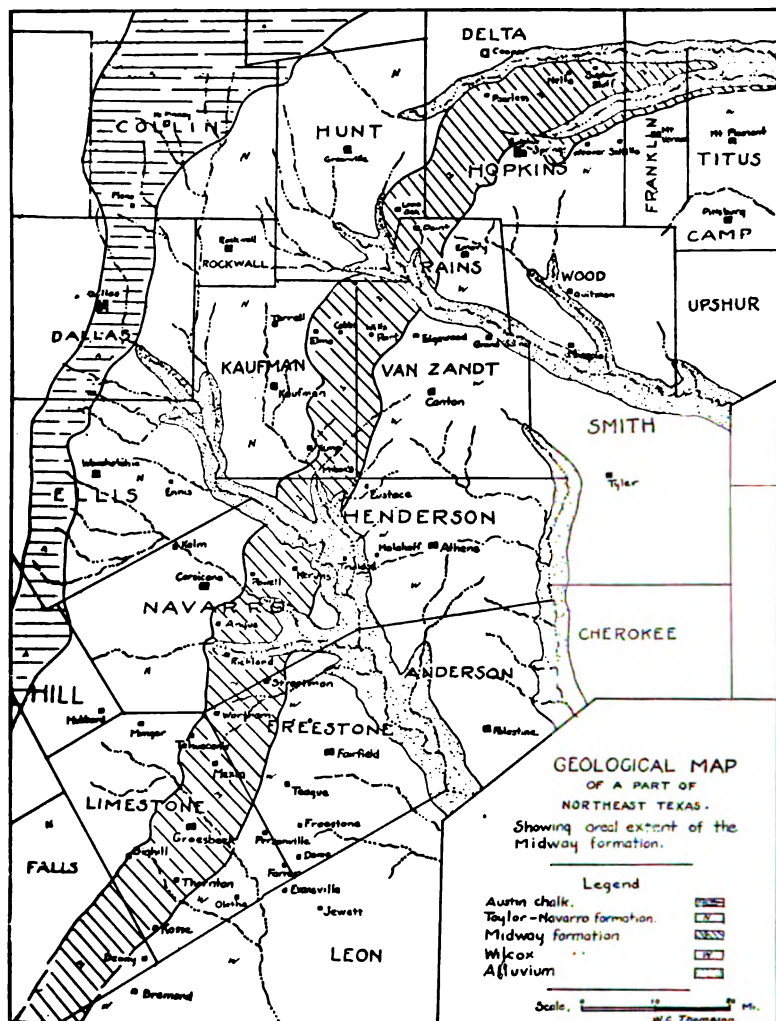


Plate 1. Geological Map of a part of Northeast Texas Showing areal extent of the Midway formation

The cause for the absence of the limestone in this district is not apparent since the upper series is not interrupted and

there is no evidence of thinning which would be responsible for the missing member. The disappearance of the limestone is probably due to several contributing conditions rather than to any one cause. Trinity River is an antecedent stream and in a large part of the area where the limestone is missing this river and tributary streams have reduced the land to low valleys and floodplains and may have eroded most of the limestone. The limestone member may also lense out or change character in this area as is the case in other areas. Aside from this, the geographic conditions during early Midway time might have been such that the limestone was deposited in a different position from its present apparent trend or even was never deposited. Such features as a land mass or, more likely in this area, an estuary might cause unfavorable conditions for the deposition of this series. It would seem that a combination of such conditions is responsible for the local absence of the basal limestone.

From southern Kaufman County northward to Sabine River the limestone outcrop is fairly continuous and is practically the same in general appearance as farther south. In this area a zone of limestone and calcareous sand and shale from 10 to 15 feet in thickness is usually present. The limestone beds are characterized by an abundance of fossils, chief among which are species of *Turritella* and certain forms of *Pecten*. The following section at Hiram in northeastern Kaufman County is typical of the area.

Section at Hiram, Kaufman County, Texas.

Hard fine grained limestone.	1 foot
Sandy shale.	10 feet
White fossiliferous limestone.	3-4 feet
Sand and calcareous shale.	40 feet
Boulder-like concretions, often several feet in diameter, composed of calcareous sandstone and shale.	

In this region, as at Mexia, the outcrop of the limestone often occurs in parallel belts due to abnormal structural conditions. The Midway limestone has been of especial value as a key bed for geologic mapping in eastern Kaufman County. Much of the structure in this portion of the country, including such areas as Beckers Gin, College Mound, Chief, and Elmo

were mapped on the basis of these beds and will be tested for petroleum within the next few months.

From Kaufman County, this series extends into the extreme southern edge of Hunt County, where the outcrop ends in the bluffs above the south fork of Sabine River.

The next exposure is found on the highlands across Sabine River, near the Hunt and Rains county line but the appearance has changed greatly. Here, there is only one hard bed about three feet in thickness. This bed is granular in texture, and contains minute fossils, noticeable among which are sharks teeth, and small chert pebbles and grains of glauconite. About three miles northwest of the outcrop just described and parallel to it, is another exposure identical in lithologic character and without doubt the same bed. A good section may be seen at a rock-quarry about four miles west of Lone Oak in Hunt County. At this quarry about fifteen feet of almost solid limestone is exposed. The variation in thickness is probably due both to lensing of the beds and to erosion.

The outcrops of this bed in essentially parallel belts at once suggest an abnormal structural feature. The exposures are not of sufficient extent to determine the structure in detail but a condition similar to that existing at Mexia, namely a faulted area, is probably present here. In this case the limestone at the quarry bears to the outcrop farther east the same relation that Tehuacana hill bears to the outcrops in the Mexia field. At Mexia there is definite evidence that a block fault or graben is present west of the field, but in this area structural conditions can only be assumed until some holes are drilled. The ridge upon which the limestone at the rock quarry outcrops, continues for some distance northeastward but the hard limestone disappears. In the area northwest of Lone Oak the hard bed is replaced by a soft sandy marl that appears only in deep ravines and roadside gullies. At many places large numbers of shark teeth have weathered from this bed.

This soft member may be traced with difficulty into Hopkins County, where it is present at a few localities near the villages of Peerless and Emblem, especially on the hills south

of Sulphur River. Its thickness rarely exceeds one foot.

A hard member of the basal Midway comes in again three miles northwest of Nelta in Hopkins County. This bed is from 18 inches to 2 feet thick and contains many fossils, and in general strongly resembles the limestone in Kaufman County. It is present in a relatively small area along a small tributary of South Sulphur Creek.

A lenticular limestone, somewhat similar in appearance to the beds at the Lone Oak quarry, outcrops for a short distance in the bluffs of South Sulphur Creek, north of the town of Sulphur Bluff but specimens of *Exogyra costata* and other Cretaceous fossils definitely place this outcrop in the Navarro. The Midway formation is concealed by the overlapping Wilcox from western Morris County eastward and is not definitely known to outcrop any farther east in Texas.

THE MIDWAY LIMESTONE EAST OF ITS BELT OF OUTCROP

As yet there are few data available that throw light upon the position and extent of the Midway limestone after it dips beneath younger beds, but there are strong suggestions that, as limestone, it is somewhat restricted in extent from east to west. Formations as old as the Woodbine sand have been identified in some of the salt domes of east Texas, but in each case the presence of Midway is doubtful. Powers⁶ describes what he thinks is the equivalent of the Midway formation on the Butler Salt Dome in Freestone County but none of the characteristic basal limestone is present. Hopkins⁷ questions the presence of Midway beds on the Palestine and Keechi domes in Anderson County. Certainly the limestone as it exists at the outcrop would be recognizable if present in these domes.

A change is also indicated by the absence of limestone in wells, east of the outcrops, where it should appear. The hard beds probably change character to the east and are present as a sandstone or shale in wells that pass through them. Too

⁶ Powers, Sidney. The Butler Salt Dome, Freestone Co., Texas. Amer. Journal of Sci. Vol. 49 Feb. 1920 pages 133-136.

⁷ Hopkins, O. B. The Palestine Salt Dome Anderson Co., Texas. U. S. G. S. Bulletin 661 1917, pp. 259.



Plate II. Midway Limestone on the Navasota River south of Mexia. Typical exposure showing irregular bedding and honeycombed character.

few well records are available thus far to prove this point, especially with reference to the greater part of east Texas, but present evidence suggests that the limestone was deposited in a rather narrow belt more or less closely associated with the old shore line.

UPPER BEDS OF THE MIDWAY

Above the basal limestone is a series of shales and concretionary beds which make up the greater part of the formation. The shales are yellow and blue in color and usually well stratified. The concretions are usually black on a fresh surface weathering to yellow or white. These concretions sometimes form a zone which may be traced over a large area, but as a rule their vertical extent is so great that they cannot be used to determine structure. Typical exposures of the concretionary beds may be seen northeast of Kerens in Navarro County, southeast of Kemp in Kaufman County and also in the Wills Point area. This upper series is sometimes differentiated locally, such as the Kemp Clays and the Basal or Wills Point Clays.

The thickness of the Midway formation as a whole is variable and there seem to be no definite figures accepted for the thickness at any given locality. Deussen⁸ gives the thickness of the formation as 250-500 feet, while Stephenson⁹ merely assigns a thickness of 200 feet. With the changes in dip and other structural features accurate measurement at any point is difficult. However, considering the width of outcrop with the average dip and also the meagre data from well records it seems that the Midway formation is at least 500 feet thick in northeast Texas.

MIDWAY-WILCOX CONTACT

In general, the contact between the Midway and Wilcox formations is characterized by a break in topography. The upper Midway is characterized by open prairie land with no timber except along the larger streams. The beginning of the Wilcox is usually marked by sandy land and heavy growth

⁸ Deussen, Alexander. U. S. Geol. Survey. Water Supply Paper 335 p. 29.

⁹ Stephenson, L. W. U. S. Geol. Survey Prof. Paper 90 p. 156.

of timber. Not infrequently the contact is marked by a low ridge of Wilcox sandstone.

ECONOMIC IMPORTANCE OF THE MIDWAY LIMESTONE

Aside from its importance from a geologic standpoint, the Midway limestone is of considerable economic importance. Since it is the only hard formation in a rather wide belt it has been used extensively as a building material, especially as crushed rock and in concrete work. Quarries are situated at Tehuacana, Richland, Beckers Gin, Lone Oak and other places from which the limestone is taken and used for road ballast and crushed rock. At certain localities, notably in the Abel Springs and McCoy area in northern Kaufman County the limestone has been burned to produce lime for mortar. It was important in this respect in the early days. Wherever the basal series of the Midway is relatively close to the surface it is usually important as a water horizon. In a large area embracing the northeastern part of Kaufman County and the northwestern part of Van Zandt County the limestone beds carry water and are usually the chief source of domestic supply. Sometimes the water is unfit for drinking purposes on account of its high lime content. The limestone is also an important water horizon in the Mexia district. Wherever the limestone is encountered water is present but the flow is exceptionally strong in wells located in the faulted zone west of the field. The town of Tehuacana is supplied with water from a well in this formation.

ORGANIC MATERIAL OF CARBONACEOUS SHALES

BY COLIN C. RAE

Considering the important progress made during the past twenty years in the methods of structural mapping and study of stratigraphy, very little advancement has been made in the identification of the organic material of carbonaceous shales or possibly limestones, of which knowledge is essential in location of prospective oil territory or extensions of proven areas.

Due consideration is given, where possible, to the amount and character of the carbonaceous or bituminous strata, but usually the dark color indicating carbonaceous material is the extent of field study. However, many dark shales often have carbonaceous coaly material, rather than the organic "kerogen," the source of petroleum. When the organic substances have been sufficiently altered to produce bituminous material, the work of the geologist is simplified, but in many cases, the shales will contain organic material rather than bituminous.

Thus it is difficult at the present time to state definitely whether the organic material in the carbonaceous shales is the proper type to produce petroleum. If some definite microscopic, chemical or physical tests could be established to indicate the identity of the organic material, which is the source of oil, then future geological field work on structure or stratigraphy, would be supplemented where possible, by tests of the shales closely associated with possible oil sands.

Sufficient work has been done to indicate that the organic material producing oil, called by some authors "kerogen" is a much varying material under microscopic study consisting of a coagulated, amorphous, organic ground mass, in which various types of fossil material, spores, seeds algae, etc., are embedded. Sometimes no identifiable remains are found. A brief resume of the microscopic work and possible identity of the unknown, amorphous, organic ground mass will probably give the foundation for more detailed work.

REVIEW OF MICROSCOPIC WORK ON CARBONACEOUS OR ORGANIC SHALES

In the microscopic study of the original organic material in the shales, some investigators used acids and alkalis, which might alter some organic constituents of the slides although giving a clearer view of fossil matter. It seems that the first studies should be made with great care to retain unaltered shale without use of possible solvents, heat or pressure.

Reinhart Thiessen of the Bureau of Mines did considerable microscopic work on the Devonian and other shales of Kentucky and Indiana. After treatment by hydrochloric acid, he found spores to be the chief recognizable plant remains, hence assigned the probable origin of oil to the spores. Spores are disc shaped plant material from which low forms of plant life, which do not have seeds, reproduce themselves. It is probable that Devonian ferns may have been the source of these spores.

However it seems that Thiessen did not sufficiently consider certain factors in his slides. The photographs show light colored spores imbedded in a much darker colored matrix. It is usual in any particular shale that the darker, black colored portion will have the greatest amount of organic material. Thiessen was unable to identify the darker, richer portion of the matrix. It presented no recognizable plant remains, but seemed to be a homogeneous mass adapting itself to the spaces between the spore material. The possible origin and character of this unknown, rich dark colored material in the slides and the organic material dissolved by acids in digesting process is what this paper will attempt to identify.

Marcus Goldman of U. S. Geological Survey in his preliminary report on the Bend series of Texas mentions the fact that the dark, rich organic matter of the richer shales and limes often has a flocculent, amorphous appearance with no recognizable plant forms.

The late Dr. C. A. Davis, of the U. S. Bureau of Mines, in his personal notes made mention of the jelly-like mass of organic substance in which the plant forms of Eocene oil shales were embedded. He also noted in some beds a marvelously complex delicate plant growth of felted character probably

similar to that described by Zalesky from the Silurian of north-western Russia.

Prof. R. D. George and others have done microscopic work on the oil shales of Colorado, Wyoming and Utah. The brown shales afforded much study of seeds, stems, cuticle, leaves, spores etc. These sections are first digested with alkali, then treated in a hydrofluoric bath for two weeks, and lastly cleaned by weak sulphuric acid. This treatment undoubtedly dissolves much of the jelly-like amorphous flocculent organic material. However the very rich lustrous black oil shales, even after treatment, rarely afford sections in which even minute plant remains can be studied. Solution tests show no bituminous matter. Thus the richest black Colorado shales, similarly to the Devonian shales and to the Bend series, show a very rich unknown dark colored organic substance in which no recognizable plant remains can be identified.

This seems to be a similar characteristic of various shales of different ages. When one considers what animal and vegetable material, the ordinary river water would show under a high powered microscope, for it would undoubtedly look like vegetal debris, and some water, instead of water, and some vegetal material, it seems very strange that if it is the plant material itself or remains of marine life from which the oil originates in these various carbonaceous shales, the richer material has little of plant remains which a high powered microscope can identify. It does not seem probable that the forms can be preserved in the poorer material, and then be completely degraded and cut into unrecognizable shreds in many richer shales. We will next consider the possible identity of this unknown organic material.

IDENTITY OF UNKNOWN ORGANIC MATERIAL

The common distribution of plant remains through many formations which are not productive of petroleum, the concentration of petroleum hydrocarbons in extensive deposits in some localities, and many other factors, such as the unknown amorphous, flocculent material in the microscopic slides of carbonaceous shales, seem to indicate the existence of an intermediate organic hydrocarbon between the organic com-

pounds of the plant or animal life and the petroleum hydrocarbons, and much evidence points to the humic acids or associated organic compounds, which are probably collected by surface waters and concentrated in certain areas by means of precipitation by electrolytes, such as would be contained in sea water or possibly in various inland seas or lakes.

Considering various types of plant life, the fruits and seeds have the principal portion of mineral matter such as phosphorus and much more nitrogen, while the bulk of material growth is chiefly composed chemically of carbon, hydrogen, oxygen and some nitrogen. When the plant or animal dies, the chief decomposition products are water, carbon dioxide, and ammonia. However the action of rains and surface waters tends to accumulate the decomposed matter in form of ulmohumic acids and ammonia before the organic compound is completely broken up. Some of this material is absorbed by the soils resulting in humus enrichments. Much of it is collected by surface waters and concentrated in the large rivers on the way to the sea.

It is difficult to give the exact chemical formula for the ulmohumic acids, as organic chemistry is still in process of development. Prominent chemists have shown that the humus acid group can become colloids, and as such are easily precipitated by sodium chloride (common salt), calcium sulphate (gypsum), iron sulphate and other electrolytes.

The difference between a colloidal solution, and a suspended solution is that the colloidal solution is absolutely uniform, and has the power of dialysis, which means diffusion through membranes such as parchment, pig bladder, collodian soaked filter paper, etc. It is now the opinion of chemists that the colloid state is of great assistance to chemical actions and is a universal possible state of matter, meaning that under certain conditions, all substances can become colloids. Gold and silver colloids are two extreme cases, while india ink, skim milk, various dyes, etc., are more practical examples. A good example of the various states of any one element would be the four stages of sulphur. First the large crystals of sulphur, secondly, the finer minute crystals called flowers of

sulphur, thirdly, a yellow colloidal solution of sulphur in benzol, fourthly, a molecular state of sulphur in a solution of carbon bi-sulphide.

The small particles in a colloidal solution have an electrical charge. Certain chemical colloidal elements are positive, others are negative. Consequently when the solution varies in temperature, alkalinity and acidity, the colloidal solution is affected. Hence the amount of dissolved humus acids in various river waters would vary with the alkalinity, temperatures and salts present in the waters, which would depend upon the type of drainage area, the climate and humidity.

The effect of alkalis and acids upon colloids is subject to variation. This action must not be confused with the action of electrolytes in precipitation. Sometimes negatively charged colloids are precipitated by a slight amount of negative acid colloids such as humus, but on addition of an excess, would not have been precipitated. Certain river waters have much negative colloidal silica with the humus, but it has not been definitely explained why it does occur. It is probable that the excess of colloidal humus has an effect upon the colloidal silica.

The amount of dissolved material in stream waters is a variable factor, but in most large rivers it amounts to millions of tons yearly. For example, the streams of the small drainage area of England and Wales carry eight million tons of dissolved material yearly. The following are a few analyses of some river waters showing the percentage of humus in this dissolved material carried by the rivers, and shows the effect of drainage area as well as humidity:

Analysis of river waters showing percent of humus in dissolved material.

James River	4.14
Nile	10.36
Hudson	11.42
Thames	12.10
Amazon	15.03
Lough Neigh (Ireland)	16.40 (boggy)
Plata	49.59
Negro	53.89
Uruguay	59.90

These analyses show that in some large rivers, many hun-

dred thousand tons of dissolved humus acids are carried to the sea each year.

When the rivers or streams reach the ocean or various inland lakes or seas, the action of the electrolytes such as gypsum, common salt, iron salts, etc., causes a precipitation of the humus material. Simultaneously, the water decreases its velocity and much sediment and material are dropped. The waters of large rivers do not immediately mix with the sea water, nor drop all sediment, but it is a gradual, assorting action which may take place for many miles. The precipitated organic material would be in a jelly-like, amorphous form, which would collect or hold various plant and marine material in the river or sea water, also much mud and sediment, sinking to bottom and becoming part of the shales or possibly limes which are being deposited in that area.

The microscopic work on various carbonaceous shales has shown that there is an unknown, jelly-like, amorphous, rich organic material. This material has the character and type of a precipitated organic compound of the humus acid group. It is incorporated in various strata, probably chiefly in shales, and in limes to much less extent. Later by means of stress, pressure, heat and other factors such as catalyzers influencing the chemical change of the organic material into petroleum, the organic compound may be converted into oil. In the absence of necessary heat, pressure, etc., it may retain its jelly-like, organic composition, and be constituent of the so-called oil shale.

Having correlated the unknown, dark, organic material in the shales with the type of material collected by streams and later precipitated and incorporated into shales and limes, the present day evidence of the association of the humus organic compounds with oil, particularly in presence of sea or inland lake waters will be considered.

PRESENT DAY OCCURRENCES OF PETROLEUM ASSOCIATED WITH ULMOHUMIC ACIDS

Binny in the London Institute of Mining Engineers in 1912 made mention of the fact that evidence of petroleum was collected from a peat or swampy bog at the time of incoming

tides. He could not explain this action, and it may be that slight amounts of petroleum are formed from the precipitated organic compounds in presence of proper catalyzers and sea water. Haseman in the American Association of Petroleum Geologists, 1921, reports certain occurrences of asphalt in very recent formations, where fresh water swamps existed adjacent to the sea, in Florida and Georgia. From the evidence, he concluded that the asphalt had been formed from the humus acid group, assisted by the presence of sea water and probably electrolytes. Haseman's paper was an important application of the humus acid precipitate theory, which was outlined by the author of the paper in a "thesis" for the University of California in 1912. While Haseman made definite statements concerning the origin of asphalt from the humus, he did not note the importance of river waters in collecting and concentrating the organic compounds.

There are a few points in the Gulf of Mexico where the heavy mud stirred to depth of a few feet will give off fine globules of oil. While there is a possibility of seepage in that area, still it checks the foregoing evidence so closely that it is worth mentioning. At first the oil bubbles were assigned to the diatoms or remains of marine life, but Dr. Harold Turner of John Hopkins University made a close study of the muds, and while diatoms were present in some barren muds, there were very few in the mud producing oil globules. It was described as black mud mixed with unidentifiable amorphous organic material and fine grains of silica. In this connection, it might be well to mention that sometimes river waters carry 20 to 50 percent colloidal silica in solution, which likewise would be precipitated by electrolytes at the same time as humus acids.

In the dead sea, oil has been distilled from the heavy black muds accumulating in the bottom, where the organic material from the stream waters could have been precipitated by the sea. In the Mediterranean, petroleum has been distilled from the heavy carbonaceous muds but the type of organic material producing it has not been studied in detail.

Bertrand and Renault in an excellent paper, reported pe-

troleum distilled from organic material consisting of algal remains buried in a humic acid jelly. They did not differentiate the humic ground mass from the fossil content. Later work by Thiessen and Jeffrey has indicated that the reported algal remains may be spore material.

The application of the identity of the ground mass as ulmohumic acid to the Eocene shales in Colorado, Utah and Wyoming is interesting. The presence of gypsum seams, iron minerals, salts, and oölitic lime deposits similar to those being formed today on shores of Salt Lake shows conditions for the sufficient concentration of lake waters, which would cause precipitation of the organic material. The vegetation at that time shows a warmer climate than at the present day, probably favoring development of plant life and humus.

If the unknown organic ground mass of petroliferous shales was an ulmohumic jelly caused by precipitation of colloidal humus by salt, gypsum, iron sulphate, or other electrolytes, the presence of one or several of these should be indicated by minerals present in the shales. Since the marine evidence of most shales shows saline conditions, and in other shales the presence of pyrite,—probably iron sulphate reduced by organic material to pyrite,—gypsum, and other materials, is common, the evidence seems to correlate the precipitation theory.

It may be possible in field work to test the brown or dark carbonaceous strata for the type of organic matter capable of producing petroleum. The color is not always a clear indication, since it may be carbonaceous rather than the ulmohumic ground mass with vegetal material such as spores. etc. Further research work will probably develop better tests along lines indicated later in this paper, but the vest pocket alcohol blow torch used by Dean Winchester with small test tube to indicate by condensation of oil globules in the glass tube, the possible petroliferous type of the formation, may prove to be valuable.

SUMMARY

Microscopic work on shales associated with oil deposits has shown the presence of an unknown, rich, dark, organic, ulmohumic, ground mass with varying, identifiable organic remains, which are sometimes missing entirely. Present day

evidence shows that asphalt can be formed from the ulmohumic acid precipitates in the presence of sea water and electrolytes. Rivers and streams act as the concentrating agents for millions of tons of organic material, which are later incorporated into marine or inland lake deposits. By subsequent pressure, heat, or catalytic agents, the organic material is converted into petroleum probably varying with the type of humic precipitate and perhaps in part with its fossil content and with the rate of geochemical change caused by pressure, heat, presence of catalytic agents and filtration by product.

Unfortunately, no detailed microchemical work has yet been done upon the shales using various solvents, pressures and heat gradually to note which substances disappear in the production of the various petroleum products, and to differentiate accurately between the ulmohumic groundmass and the varying types of fossil contents. If definite knowledge could be obtained as to whether the source of petroleum is the ulmohumic ground mass or certain identifiable fossil material, or both, and that certain tests, probably microchemical, would show the value of various types of carbonaceous shales as the source of petroleum, it would undoubtedly be very valuable in the location and search for new oil areas.

The research work to establish and identify the organic materials would require many months of careful microchemical work. Besides being important to future geological work, the research may show the process of transmission of certain organic substances into petroleum. David White, Chief Geologist of the United States Geological Survey, is undoubtedly the most capable man to direct and manage the research work, and it seems that the expenditure of money to investigate thoroughly the source of oil from shales associated with oil deposits, would be well justified.

A PRELIMINARY STUDY ON THE RECOVERY OF OIL BY SINKING SHAFTS AND DRIVING GALLERIES

LOUIS FRANKLIN

INTRODUCTION

It is generally accepted that the compressed and absorbed gases in an oil sand are the chief expulsive energies in the sand, the viscosity of the oil, the nature of the pores, and friction of the oil passing through the pores constituting the chief restraining forces.

When an equilibrium is finally established in a sand, between these expulsive and restraining forces, it is estimated that 40 to 60 percent of the oil is retained in the ground; some estimates of this unrecovered portion are as high as 90 percent.¹ The vacuum pump, air lift pump, swabbing, bailing, agitation devices, all have failed, more or less, to recover entirely this remaining portion of oil. The relative failure of these devices combined with the increased demand for oil has resulted in an attempt to mine the 40 to 60 percent oil remnant by sinking shafts and driving galleries into the oil sand.

The idea of digging shafts and driving tunnels to obtain oil is not a new one. Pits were dug for oil throughout the ages and was the common practice of the American Indian. In the nineteenth century shafts and galleries were worked on a commercial scale in Pechelbronn, Alsace, but were abandoned on account of the large quantities of gas that were encountered. Over thirty-five years ago the Union Oil Company of California² had dug twenty-six tunnels to reach an oil formation on the southern flanks of Sulphur Mountain where conditions are favorable for such methods. These tunnels were intended originally for development purposes, but when completed were used as a source of production. The most successful attempt to mine oil by shafts and galleries on a

¹ Lewis, J. O., Methods of increasing the recovery of oil from sands. Bull. 148, Bureau of Mines, 1917, p. 26.

² Union Oil Co. of California. Bull. No. 6. Aug. 1921, p. 5.
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modern scale was in Pechelbronn, Alsace, where the method had been previously tried and abandoned in the 19th century. The war demand for oil was so great that in 1916 shafts were again sunk in the mines of Pechelbronn and oil was drained by driving galleries and washed from the sands.³ This last attempt proved very successful.

PHYSICAL FEASIBILITY OF MINING PETROLEUM BY SHAFTS AND GALLERIES

The Establishment of an Equilibrium in an Oil Sand

Two important changes take place in the oil sand when it is tapped. First, the gas pressure decreases over the entire sand; second, the diminishing gas pressure permits some of the gas absorbed in the oil to bubble out and press its way through the pores of the sand. This bubbling or "fizzing" action spreads over the entire sand, increases in vigor with the decline in compressed gas pressure, and sets the oil in motion. In time, the absorbed gas escaping from the oil does not flow out of the sand into the well but fills the pores of the upper layer of the sand, which have drained first, and instead of forcing the oil out of the lower pores, due to insufficient pressure, prevents the remaining absorbed gas from escaping, and in this way stops the "fizzing" action in the sand. The movement of oil through the sand ceases when the bubbling activity of the gas stops and an equilibrium is established. The pores in the upper parts of the sand remain filled with gases and the pores in the lower parts of the sand stay filled with isolated drops of oil separated by pores and gas bubbles. Thus the absorbed gases which in the early history of the sand set the oil in motion, in a later stage prevent oil movement.

Failure of Surface Devices to Destroy Equilibrium

The well at this stage yields very little oil, and recovery devices are tried. A vacuum pump applied to the well has little effect upon the oil content of the sand. By creating lower air pressure in the well the gases in the upper layers of the sand will be set in motion and may sufficiently decrease

³ De Chambrier, Paul, Journal of the Institution of Petroleum Technologists. Vol. 7, No. 27, July 1921, p. 178.

in pressure to create some "fizzing" action in the lower parts of the sand, but insufficient to cause much oil flow.

Greater recovery of the oil left in the sand is obtained by forcing compressed air into the well.⁴ The compressed air has a double effect upon the equilibrium that has been established between the oil and gas in the sand. First, the pressure in the sand is increased; and second, the bubbling action will be rejuvenated to a greater degree than by the vacuum pump. This dual effect of the compressed air increases the oil recovery. At its best this method has its mechanical and physical limitations. The air pressure is insufficient to overcome completely the friction caused by the viscosity of the oil and it cannot overcome entirely the capillarity in the pores.⁵ The compressed air method which is best applied to a uniform sand with connected large pores, is least effective in a variable sand, and "should be used as a last resort when the ordinary methods are no longer effective."⁶

Bailing, swabbing, and agitating devices are convenient at times but have both mechanical and cost limitations.

How Shafts and Galleries Recover all the Oil

Surface devices fail to destroy the equilibrium between the absorbed gas and the immobile gas in the upper pore spaces. This balance is completely destroyed and direct access to the oil is possible when a shaft is sunk to the bottom of the sand and galleries driven into the sand at convenient distances apart. When a gallery is driven into the sand the immobile gas in the upper parts of the sand is removed, the absorbed gases are again able to escape, the isolated drops of oil unite and seep into the galleries, from where the oil flows in channels constructed in the floors of the mine into a collecting pool at the bottom of the shaft and then is pumped to the surface.

The oil-soaked and oil-covered sand that is brought to the surface by tunneling adds another large percentage to the oil

⁴ Arnold, Ralph and Garfias, V. R., *Methods of Oil Recovery in California*, Tech. Paper 70, U. S. Bureau of Mines, p. 14.

⁵ Arnold and Garfias, loc. cit. p. 21.

⁶ Arnold and Garfias, loc. cit. p. 16

recovered by seepage and mining. The oil from this sand is recovered by washing with hot water. The importance and magnitude of the quantity of oil that can be recovered by washing oil sands cannot be overestimated. Elliott⁷ states that in California, "From the data collected, it is estimated that 2,359,100 barrels of oil valued at more than \$3,500,000 could be obtained from the sand piles about producing wells and from out-crops in the vicinity of the fields." What immense quantities of oil could then be recovered by actually mining the oil soaked sands?

Mining of oil by shafts and galleries physically practicable.

That the mining of oil by shafts and galleries is physically practicable has been demonstrated in the mines of Pechelbronn, Alsace. While the physical conditions in Pechelbronn are very favorable for mining operations there are numerous places in the United States and in the world, where similar or equally favorable conditions exist. The presence of water formations makes mining operations more difficult but this is easily overcome by proper timbering. The greatest difficulties encountered in the operations at Pechelbronn are those of gas and fire. By a very thorough and good ventilating system and the proper kind of working methods the danger of gas is almost entirely eliminated. The danger of fire is prevented by very careful operations. Instead of using a pick ax, which when struck against a rock will give off sparks, the compressed air drill is used. The latter does not give off sparks and facilitates the work. A great deal of precaution is taken in the lighting, working and equipment operations of the mine. Special devices and fire proof rooms are put in the mine for safety. There is little doubt that with improved mining methods the mining of oil can be made as safe as any other kind of mining.

Results of Mining Oil by Shafts and Galleries.

The outstanding result of the Pechelbronn mines is the fact that oil was obtained from sands, which were believed to be

⁷ Elliott, A. R., Recoverable Oil By-product Sands and Outcrops, Reports of Investigations, Bureau of Mines, Nov. 1920. Serial No. 2182.

exhausted, and in two to five times the quantity that had previously been produced by the wells. This large recovery came from the richest parts of the beds, and if the leaner parts of the sand had been worked the ultimate total recovery would have been still greater.

ECONOMIC CONSIDERATIONS.

The mining of oil by sinking shafts and driving galleries is economically feasible. The cost per barrel of oil produced by wells based on the cost of drilling and operating a well is not commensurate with the cost of oil produced by sinking a shaft and operating a mine. The Federal Trade Commission in its Report on The Pacific Coast Petroleum Industry found that "The chief factor in cost seems to be the volume of production per well," The more productive wells show the lower average cost per barrel.

Chambrier⁸ calculates that in the United States it would take "116 productive borings in a new district, in order to obtain a quantity of oil equal to that produced by underground workings of abandoned oil fields." Chambrier bases his calculations on the fact that in five years the "galleries" at Pechelbronn will produce 150,000 tons of oil and that during a period of ten to fifteen years the average American well will produce about 1300 tons of oil; thus 150,000 divided by 1,300 equals 115.4 Mr. Chambrier's estimate of American production per well may be rather low but the fact still remains that, whereas one shaft will produce at least two times as much oil from a sand that has been exhausted by wells, it takes many wells to produce an equal quantity from a new sand. Moreover, whereas immense sums of money are spent in wildcatting, an oil mine is developed where oil is known to be present. Considering therefore, the quantity of oil that can be recovered by the shaft and gallery method compared to the number of wells that would have to be drilled to yield an equal quantity of oil and the wildcatting expense that is avoided, an oil mine from 500 to 800 feet deep is financially possible.

There are, in the United States, many shallow oil pools

⁸ De Chambrier, Paul, loc. cit. p. 188.

exhausted or nearing exhaustion whose life could be prolonged many years and production greatly increased by the development of oil mines. The development of oil mines in the United States would increase the oil reserve at least 50 percent, and large quantities of oil valued at millions of dollars would be added to the petroleum industry.

CONCLUSION.

The subject as presented in this paper is preliminary and introductory. The writer has purposely omitted numerous problems for more exhaustive treatment in the future. Nothing has been said of the quality of the oil obtained from oil mine workings or the technique of mining and washing of oil sands. These problems can be solved and it is merely a question of time when large quantities of oil will be recovered by sinking shafts and driving galleries.

EDITORIAL

At the last annual meeting of the Association, held in Oklahoma City, provision was made for holding mid-yearly meetings in localities situated outside the Mid-Continent region. A cordial invitation has been received from the Rocky Mountain membership to meet with them in Denver in October, which after mature deliberation, the Executive Committee has decided to accept. The date set for the meeting is October 26, 27, and 28; announcement of further particulars will be made later.

In the past the geographic distribution of the membership has been the controlling factor in selecting a place for the annual meeting. Although oil geologists are ordinarily a migratory group, the fact remains that a majority of the members of the Association have their residence in the Mid-Continent and there is little prospect of a change in this situation within the near future. The consensus of opinion at Oklahoma City was that the annual business meetings should continue to be held at points most accessible to the majority of the members, and that the activities of the Association should be carried, through mid-yearly meetings, to the several important centers of geological activity outside the Mid-Continent.

The advisability of holding meetings distant from the large body of the membership has been widely discussed during the past several years and has always had many supporters. In the Rocky Mountains; in California; in the states east of the Mississippi; and in New York and Washington, there are important contingents of oil geologists, all interested in Association affairs, though many are prevented by the long distance from attending meetings in the Mid-Continent. The Association owes a duty to these men to hold meetings, occasionally at least, at points near enough for them to attend, particularly where any considerable group of members are within reach of a recognized headquarters, as is the case in Denver.

It is hoped that this will be the first of a series of regional meetings although the holding of similar meetings will no doubt depend largely upon the success of the present venture. Those who are acquainted with the able group of geologists resident in and around Denver will readily concede that the meeting will be a success in so far as the efforts of the local men can make it such; it remains to be seen how successfully their efforts will be seconded by the attendance and contribution of papers from the general membership.

The date of the meeting has been set for October 26-28th inclusive, in order to insure a large attendance of the geologists working in the Rocky Mountain region. The western field season will then be near its end; there will be no Osage sale during October; field operations will be at a low ebb owing to the present necessity of curtailing drilling in the Mid-Continent fields; and these several factors should make it possible

for many busy geologists to attend whose duties would not otherwise permit.

The Executive Committee makes an urgent appeal to the general membership to attend the Denver meeting. A thoroughly enjoyable visit is in prospect. Papers on subjects of general geologic interest are solicited for the program. This is a purely technical session,—no association business will be transacted, and it is hoped that there will be a liberal contribution of papers, all of which will later be published in the Bulletin.

W. E. WRATHEE.

GEOLOGICAL NOTES

WILDCAT OIL EXPLORATION IN SOUTH-CENTRAL ARKANSAS

Of the many wells that have been drilled in south-central Arkansas for oil several apparently stopped short of the sand that yields the oil at El Dorado in Union County, and the greater number did not reach the sand that yields oil in the Haynesville field, in Claiborne Parish, La. Furthermore, practically all drilling has been done with rotary tools, a method which not only yields inaccurate records of the formation penetrated but which also frequently prevents the recognition and testing of oil sands that may be drilled through.

Several sands in northern Louisiana, below the Nacatoch have produced much more oil than the Nacatoch, and in some of the fields the Nacatoch is practically barren, in spite of the immense volume of oil in the underlying sands. The deepest formation in this region that now seems worth testing is estimated to lie 4,000 or 5,000 feet below the surface and may be below profitable drilling depth. This formation is the Trixity, which in Pike and Sevier counties, Ark., contains asphalt deposits that represent the meager remains of what were once rather large bodies of oil.

Although the character of the formation in southern Arkansas may require the use of the rotary drill, operators should realize its shortcomings and employ methods that will insure, so far as possible, detection of showings of oil and gas. Cores should be cut from all beds penetrated that yield showings and particularly from a sand near the base of the Midway formation and from sands in the Nacatoch, Marlbrook, Browntown, Blossom, Eagle Ford, Woodbine, and Trinity formations, whether or not oil showings are observed in the sludge.

The ages, relative positions, and thickness of the formations encountered in drilling in south-central Arkansas must be determined if the search for oil is to be carried out effectively and economically. These determinations are difficult because of the similarity of the beds of the several formations, and can be made precise only with the aid of fossils. The approximate boundaries of the larger units, however, may be determined from the character of the beds as shown by well records. The following descriptions of formations encountered by drillers in Union County, Ark., are the result of a detailed study of many well records. Inaccuracies² in the well records may have caused like inaccuracies in the interpretation of the stratigraphy.

Probably all the rocks that cover the surface of Union County belong to the Claiborne group of the Eocene series of the Tertiary system, which in this general region is divided into two formations, the Yegua above and the St. Maurice below.

Yegua (?) formation.—Recent determinations of fossil plants by E. W. Berry indicate that the Yegua (?) formation is probably present in Union County, and that it comprises the surface beds over most of the

county. The beds that are probably to be assigned to the Yegua ("Cockfield") formation are recorded in well records as alternating layers of sand and gumbo, some shale and calcareous material ("boulders" and "rocks") and a little lignite. They may be distinguished from the underlying beds by their dominant sandiness. These beds probably attain a maximum of slightly more than 450 feet in the southeastern part of the county.

St. Maurice formation.—The strata in this area which are here identified as the St. Maurice formation are commonly recorded in drillers' logs as layers of shale and gumbo with many "boulders" and "rocks" and some sandy material. The St. Maurice is much freer from sand than the formation above and below it. It probably ranges in thickness from 90 feet in the northwest corner of the county to about 200 feet in the southeastern part.

Wilcox formation.—The Wilcox formation is generally shown in logs as thick alternating layers of sand, sandy gumbo, and shale, with some zones marked by "rocks" and "boulders," although subordinate amounts of gravel and lignite are occasionally noted. This formation can be recognized by an upper sandy group and a lower shaly group which contains less sand. Its thickness averages about 600 feet throughout Union County but increases slightly toward the east.

Formations similar in composition to the Wilcox have yielded small quantities of oil in Louisiana and Texas, and the expectation that some oil may be obtained from this formation in restricted areas is not unreasonable. A careful watch should therefore be kept for indications of oil or gas while wells are penetrating these beds.

Midway formation.—The beds referred to the Midway formation are recorded by the drillers as "boulders," "rocks," and layers of sand, gumbo, and shale, with more or less chalk, limestone, and gypsum. Recent microscopic studies of cuttings from wells in the El Dorado field by James Gilluly, of the U. S. Geological Survey, have shown these beds to include some lignite. This occurrence of carbonaceous material in the Midway, although by no means widespread, is nevertheless not unusual. This formation is characterized throughout by its relative hardness.

The greatest known thickness of the Midway at its outcrop is about 260 feet,¹ but this measurement was taken near the shore line of the embayment in which the formation was deposited. The character of the strata penetrated indicates that the formation probably attains a maximum thickness of slightly more than 500 feet in Union County.

Many wells drilled in south-central Arkansas have obtained showings of oil or gas or flows of water in a sandy bed near the base of this formation. At only a few wells, however have tests been made to ascertain

¹Kennedy, William, A section from Terrell, Kaufman County, to Sabine Pass on the Gulf of Mexico: Texas Geol. Survey. Third Ann. Rept., p. 49, 1892.

the true value of these showings. Especially in the El Dorado field has this bed remained untested.

Arkadelphia clay.—The Arkadelphia clay of the Upper Cretaceous or Gulf series is in general easily recognized by its thickness and its freedom from sand. The strata recorded are mainly shale and gumbo, which are generally accompanied by many layers of "boulders," "rocks," chalk, limestone, and gypsum, and in a few wells layers of sandy shale. A very noticeable group of chalky or calcareous beds makes up the lower 175 or 200 feet of the Arkadelphia. The thickness of this formation averages about 550 feet in the western part of Union County and increases eastward, possibly to as much as 600 feet near the eastern boundary.

Nacatoch sand.—The drillers' log record the Nacatoch sand as beds of hard sand, shale and limestone with many layers of "rocks," "boulders," and "pyrite" and some gumbo and chalky material. The upper part is commonly hard and sandy; the lower varies from slightly calcareous shale to hard limestone, although it usually includes thin sandy layers. The thickness ranges from 150 to 200 feet.

The Nacatoch has been identified by its fossils as the producing sand at El Dorado.² The oil there is obtained from three or four discontinuous layers of sandstone in the upper 50 feet of the formation.

Marlbrook marl.—The Marlbrook marl is recorded as shale, chalk, "boulders," limestone, and lesser amounts of gumbo, "rocks," and "pyrite," and some sandy shale. This formation consists typically of shale and varying amounts of calcareous material. It ranges in thickness from about 300 to nearly 350 feet.

A group of sandy shales between 400 and 500 feet below the top of the Nacatoch usually yields water wherever it is penetrated. The beds at this horizon may contain oil or gas where the structure is favorable.

Annona tongue of the Austin chalk (?).—Fossils obtained from one of the wells³ indicate the Marlbrook age of strata at least 250 feet below the base of the Nacatoch sand, and as no marked change in the character of the sediments down to the Brownstone marl is recorded, the Annona tongue or Austin chalk may be absent here. However, as this tongue, in its area of outcrop, varies from typical chalks to calcareous clays, it is probably present in Union County, but because of this lithologic variation it may not be easily distinguished from the overlying Marlbrook marl. The boundary between the Marlbrook marl and the Annona tongue of the Austin is provisionally drawn at the upper surface of a persistent limy or chalky series. As thus identified the Annona tongue in Union County consists of strata recorded in logs as limy shale, gypsum, and gumbo, with some "rocks," sandy shale, or chalk; its thickness ranges from 60 to 100 feet.

²U. S. Geol. Survey Press Notice: Oil from the Nacatoch sand, El Dorado, Ark., Feb. 7, 1922.

³U. S. Geol. Survey Press Notice: Oil from the Nacatoch sand, El Dorado, Ark., Feb. 7, 1922.

Brownstown marl.—The strata referred to the Brownstown marl are dominantly calcareous sandy shales. They are usually called sandy shale, hard shale, "rock," sand, and gumbo in drillers' logs. Subordinate amounts of limestone, "boulders," "pyrite," gypsum, and chalk are frequently noted. The thickness of the Brownstown marl ranges from about 200 to nearly 300 feet and apparently increases westward.

The formation is unique among those penetrated in that its thickness seems to decrease eastward across Union County. This fact doubtless is associated with a marked increase in sandiness of the Brownstown from its outcrop in Hempstead County southeastward through Union County. Any conclusions as to the cause of these changes would be unwarranted if based entirely on evidence furnished by records of rotary-drilled wells, but the presence of these sandy layers may well justify a thorough test of this formation.

Blossom (?) sand.—A group of beds below the Brownstown marl, consisting of about 65 feet of sandstone, shale, and some calcareous layers, is probably to be correlated with the upper part of the Bingen formation of southwestern Arkansas and is therefore tentatively referred to the Blossom sand. The Bingen formation is considered by L. W. Stephenson "as the probable near-shore equivalent of the Blossom sand, the Eagle Ford clay, and part of the Woodbine sand, but these formations are probably represented in part by unconformities within the Bingen and at its base. Indeed, it is possible that the Woodbine sand is entirely represented by the unconformity at the base of the Bingen." Sandy layers in the upper part of the Blossom (?) sand commonly carry water and are thought to correspond to the oil sand or sands in the Haynesville field, in Louisiana, although the formations there have not been positively identified. The Blossom (?) sand lies from 800 to 850 feet below the top of the Nacatoch sand over most of Union County and probably about 810 to 830 feet in the productive part of the El Dorado field.

Eagle Ford (?) clay.—The several hundred feet of calcareous or limy shales below the Blossom (?) sand that have been penetrated in Union County probably belong to the Eagle Ford (?) clay of Upper Cretaceous age. In the logs of some wells in and near Union County a few red layers are recorded from these shales (see the accompanying cross section), and in parts of the Bingen formation of southwestern Arkansas that are presumably to be correlated with the true Eagle Ford clay much reddish material has been noted, both at the outcrop⁴ and in wells.⁵

The principal oil sands of the Caddo and DeSoto-Red River districts,

⁴Miser, H. D., and Purdue, A. H., Gravel deposits of the Caddo Gap and De Queen quadrangles, Ark: U. S. Geol. Survey Bull, 690, pp. 22-24, 1919.

⁵Miser, H. D., and Purdue, A. H., Asphalt deposits and oil conditions in southwestern Arkansas: U. S. Geol. Survey Bull. 691, pp. 282-291, 1919.

to 1,400 feet below the upper surface of the Nacatoch. So far as known, this horizon has not been reached in Union County.

A Deep Well near El Dorado.—Detailed information regarding the nature of the beds penetrated may be obtained from the following record of one of the deepest wells in Union County:

Driller's record of Hammond Well No. 1, of Cooper & Henderson Oil Co., is SE¼ SW¼ sec. 19, S. 17 W., R. 15 W.

(Elevation above sea level about 204 feet. Geologic correlations by U. S. Geological Survey. All formational boundaries are fixed tentatively except that between the Arkadelphia and Nacatoch.)

Material	Thick- ness	Depth	Material	Thick- ness	Depth
Eocene series:			Gumbo	20	989
Claiborne group:			Sand	18	1,005
Yegua (?) formation:			Sandrock	19	1,024
Surface sand	30	30	Midway formation:		
Sand	20	50	Hard sand	6	1,030
Gumbo	11	61	Gumbo	6	1,036
Packed sand	6	67	Gummy shale	20	1,056
Hard sand	20	177	Sand & boulders	27	1,083
Packed sand	40	110	Gumbo	15	1,098
Hard sand	45	155	Sand & sandrock	7	1,105
Rock	2	157	Broken formation	36	1,141
Hard sand	20	17	Sandy gumbo	15	1,156
Gumbo; set 12½-			Gumbo	71	1,227
inch casing	4	181	Shale	12	1,239
Gumbo	6	187	Sand & boulders	11	1,250
Sand and boulders	6	193	Gumbo	34	1,284
Packed sand and			Rock	3	1,287
boulders	20	213	Gumbo	14	1,301
Gumbo	25	238	Lignite	5	1,306
Rock and sand	2	240	Gumbo	34	1,340
Packed sand	10	250	Rock	1	1,341
Sandrock	5	255	Sand	12	1,353
Sand and Boulders	3	258	Sand & boulders	8	1,361
Sand, boulders,			Gypsum	31	1,392
and gumbo	100	358	Gumbo	119	1,511
St. Maurice formation			Rock	6	1,517
(position of contact			Upper Cretaceous or Gulf		
doubtful; lies above in			series:		
the 100 feet of sand,			Arkadelphia clay:		
boulders, and gumbo):			Gumbo	33	1,550
Sand and boulders	18	376	Hard shale	5	1,555
Rock	2	378	Gumbo	40	1,595
Packed sand	9	387	Shale	5	1,600
Rock	3	390	Gumbo	30	1,630
Gumbo	10	400	Gummy shale	64	1,694
Sand and gumbo	20	420	Gumbo	52	1,746
Gumbo	22	442	Shale & gumbo	65	1,811
Wilcox formation:			Shale & boulders	10	1,821
Boulders	62	504	Shale	23	1,844
Sand & boulders	14	518	Gummy shale	18	1,862
Packed sand	18	536	Shale & gumbo	30	1,892
Boulders	36	572	Gumbo	27	1,919
Sand & boulders	130	702	Gypsum	10	1,929
Gumbo	6	708	Hard shale	20	1,929
Sand & boulders	43	751	Gumbo	47	1,976
Gumbo	54	805	Gumbo & shale	44	2,020
Gumbo & boulders	8	813	Hard shale & gumbo;		
Rock	4	817	set 8¼-inch		
Gumbo	48	865	casing	25	2,045
Rock	3	868	Gumbo	5	2,050
Gumbo & boulders	38	906	Gumbo & shale	46	2,096
Gumbo	5	911	Shale & gumbo	15	2,111
Gumbo & boulders	42	953	Nacatoch sand:		
Packed sand	10	963	Hard lime & shale	6	2,117
Broken sandrock	6	969	Gumbo	20	2,137

Material	Thick- ness	Depth	Material	Thick- ness	Depth
Broken rock	3	2,140	Hard sandy shale	10	2,765
Sand	8	2,148	Gumbo	9	2,774
Broken rock	2	2,150	Sand, showing salt-		
Sand	10	2,160	water	6	2,780
Rock	4	2,164	Gumbo	12	2,792
Sand	6	2,170	Hard gummy		
Shale & boulders	14	2,184	shale	22	2,814
Gumbo	5	2,189	Rock	16	2,830
Gummy shale	24	2,213	Hard sandy shale	47	2,877
Shale & gumbo	48	2,261	Gumbo	5	2,882
Gummy shale	26	2,287	Hard shale	12	2,894
Shale & lime	14	2,301	Rock	4	2,898
Marlbrook marl:			Shale	3	2,901
Shale & boulders	45	2,346	Shale & gumbo	5	2,906
Gummy shale	41	2,387	Hard sandy chalk	4	2,910
Shale & boulders	14	2,401	Sandy chalk	14	2,924
Hard shale	110	2,511	Hard shale	15	2,939
Salt-water sand	8	2,519	Blossom (?) sand:		
Rock	2	2,521	Sand	16	2,955
Sandrock	7	2,528	Rock	3	2,958
Sandy shale	2	2,530	Sand	2	2,960
Gummy shale	5	2,535	Sandrock	2	2,962
Rock	2	2,537	Gumbo	20	2,982
Gummy shale	7	2,544	Sandy shale	8	2,990
Shale	4	2,548	Shale & boulders	1	2,991
Sandy shale ^a	4	2,552	Rock	1	2,992
Hard shale	13	2,565	Sand	6	2,998
Rock	2	2,567	Sand & gravel	7	3,006
Gumbo	57	2,624	Eagle Ford (?) clay:		
Hard shale	5	2,629	Gumbo	14	3,019
Annona tongue of			Gummy shale	7	3,026
Austin chalk (?)			Gumbo	22	3,048
Broken sandrock	8	2,637	Gummy shale	9	3,057
Hard shale	13	2,650	Broken limerock	28	3,085
Gumbo	12	2,662	Shale	7	3,092
Hard sand	3	2,665	Broken limerock		
Rock	4	2,669	& shale	22	3,114
Gumbo	6	2,675	Shale	6	3,120
Lime & shale	25	2,700	Broken limerock	20	3,140
Rock	2	2,702	Shale	6	3,146
Browntown marl:			Broken limerock		
Lime & shale	25	2,727	& shale	17	3,163
Gumbo	7	2,734	Broken lime &		
Rock	6	2,740	shale	37	3,200
Gumbo	15	2,755			

^a A small fossil obtained from this depth indicates that these beds are no older than the Marlbrook marl. U. S. Geol. Survey Press Notice: Oil from the Nacatoch sand, El Dorado, Ark., Feb. 7, 1922.

Geologic Structure in the Region.—The accompanying cross section, from the vicinity of Centerpoint, Howard County, Ark., in the Caddo Gap quadrangle, to a point about 10 miles east of El Dorado, Union County, shows the general slope and the general increase of thickness of the formations as the center of the embayment is approached is readily apparent.

The elevation of the surface as shown is based on a partial revision of a map previously published by the Survey,⁷ and is included in this diagram to show the relation of outcrops to formations below the surface and the depth of the oil and gas bearing sands. Topographic details

⁷Harris, G. D., Oil and gas in Louisiana: U. S. Geol. Survey Bull. 429, pl. 12, 1910.

*Elevations of Nacatoch sand and intervals between Nacatoch and and Blossom (?) sand
at some wells drilled in south-central Arkansas.*

Company and lease.	Location				Reported Total depth of well	Depth to top of Nacatoch sand	Eleva- tion of well.	Depth of Nacatoch sand below sea level.	Interval be- tween top of Nacatoch sand and top of Blossom (?) sand.
	Well No.	Sec.	T. S.	R. W.						County.
Carlton & Owens, McCough lease..... Penn.-Wyoming Oil co., Union Sawmill. lease.....	1	SW ¼ SW ¼ 16	17	13	Feet. 2,136	Feet. a 2,350	Feet. b 262	Feet. a 2,088 ?	Feet. Feet.
E. M. Brown Goodwin lease.....	1	NE ¼ SW ¼ 16	21	18	3,089	c 2,386	b 209	c 2,177 ?	.....
Wilson Oil Co., Moody lease.....	1	NW ¼ SW ¼ 16	17	14	2,634	2,160	b 213	1,947	.....
South Arkansas Oil & Gas Co., McCurry lease.....	1	NW ¼ SW ¼ 19	17	14	2,815	2,220	b 252	1,968	.....
E. M. Brown, Grace lease.....	1	SW ¼ NE ¼ 3	18	14	2,190	2,165	b 165	1,955	.....
Quaker City Petroleum Co., Mittendorf lease.....	1	SW ¼ SE ¼ 15	17	15	2,160	a 2,250	b 253	1,997 ?	.....
Cooper & Henderson, Hammond lease.....	1	SE ¼ SW ¼ 19	17	15	3,010	2,141	b 192	1,949	834
Carter & Morgan, Syndicate, McKinney lease.....	1	SE ¼ NW ¼ 4	18	15	3,200	2,11	b 204	1,907	828
Mountzet al., Tillman lease.....	1	NE ¼ NE ¼ 9	18	15	2,881	2,115	b 206	1,909	.....
Congress Oil Co., Swilley lease.....	1	NW ¼ NE ¼ 8	19	15	2,140	2,140	b 232	1,908	.....
White Oil corp., Murphy LanderEdgar Lumber Co. lease.....	1	SE ¼ NE ¼ 5	19	15	2,522	c 2,120 ?	b 227	c 1,883 ?	.....
Mitlo Drilling Co., Robins or Trimble lease Nebraska Oil Co., Gallagher lease.....	1	NW ¼ SW ¼ 22	18	16	3,025	2,025	b 159	1,886	830
Walker Drilling Co., Flourney lease.....	1	NE ¼ SE ¼ 3	17	17	2,586	2,094	b 182	1,912	.....
Love Petroleum Co., Darden or Edgar Lumber Co. lease.....	1	NE ¼ SE ¼ 3	17	17	2,110	1,938	b 178	1,760	.....
Forest Oil Co., Mayfield lease.....	1	SE ¼ NW ¼ 23	17	17	2,533	1,980	b, d 220	1,760	.....
Hinton & Mattocks, Murphy lease.....	1	NE ¼ NE ¼ 21	18	17	2,505	2,112	c 256	1,856	.....
Carter Oil Co., at Hadnett, Ark. Trinity Petroleum Co., Realty Colo lease	1	SW ¼ SE ¼ 29	19	17	2,914	c 2,098 ?	c 300	c 1,798 ?	812
Louisiana Oil Refining Co., Allen lease.....	1	NW ¼ NW ¼ 28	14	18	2,008	2,110	b 234	1,876	f (?)
	1	NE ¼ NE ¼ 28	14	18	3,240	c 1,790 ?	c 200	c 1,590 ?	9516 ?
	1	NW ¼ NW ¼ 21	18	18	2,800	1,967	c 275	f 1,692 ?	9809 ?
	1	NW ¼ SE ¼ 13	15	19	2,777	1,720	b 170	1,550	842

a Nacatoch sand not reached. Depth to top estimated.

b Well elevations obtained from the oil companies; fairly reliable and, except for isolated wells far from the railroads, are probably correct within 20 feet. Elevations near El Dorado are based on the bench mark at the El Dorado Court House, the true elevation of which is about 3 feet above that used for it.

c The upper surface of the Nacatoch sand could not be recognized definitely from the driller's log.

d Two well elevations are given in this section. Uncertainty exists as to which is the proper one.

e Well elevations determined by estimation and from map in U.S. Geol. Survey Bull. 429 (Pl. 12). May be as much as 100 feet in error.

f Blossom (?) sand could not be recognized from the driller's log.

g The upper surface of neither the Nacatoch nor Blossom (?) sand could be recognized definitely from the driller's log.

near the wells are necessarily obscured because of the exaggerated width of the graphic logs. The records of the Nashville, Hope, and Bodcar wells with correlations⁸ and the outcrops of the formations⁹ were taken.

The strata recorded in a number of the available logs of wells drilled in and near Union County were also correlated and the results are given in the descriptions of the formations. Maps showing the structure of the Nacatoch and other formations in south-central Arkansas have been prepared by Veatch.¹⁰ A general structural contour map of Union County has not been made, as a sufficient number of well logs for that purpose has not been obtained, but the position relative to sea level of the upper surface of the Nacatoch sand and other interesting features of the wells studied are given in the preceding tabulation.

W. W. RUBEY.

EL DORADO OIL FIELD IN ARKANSAS NOT ON AN ANTICLINE

DISCOVERY AND DEVELOPMENT

The El Dorado oil field, in Arkansas, was discovered by the Constantine Refining Co., when their Armstrong No. 1 well, in sec. 1, T. 18 S., R. 16 W., struck an immense flow of gas, estimated at 40,000,000 cubic feet a day, and a small quantity of oil. The oil men of the mid-Continent region paid comparatively little attention to this discovery for several months, although a few companies, acting on the advice of geologists, leased some land near the gas well, but when a well drilled by Mitchell & Busey in sec. 31, T. 17 S., R. 15 W., came in, on January 10, 1921, with a flow of about 1,500 barrels of oil a day, and perhaps ten times that much water, there was a stampede for the field. Leasing and drilling were pushed with an intensity so tremendous that in spite of several months' delay in getting an adequate pipe-line outlet for the oil produced the field was developed with remarkable rapidity. The oil sand is only about 2,150 feet below the surface, and the rocks above it are mostly beds of shale and clay that are easily penetrated by the rotary drill. Wells that gave a large output were the rule rather than the exception, several yielding more than 10,000 barrels a day, although most of these wells produced much salt water with the oil. The output reached about 82,000 barrels a day during the week ending August 20, 1921, but declined rapidly to about 32,000 barrels a day during the

⁸Miser, H. D., and Purdue, A. H., Asphalt deposits and oil conditions in southwestern Arkansas: U. S. Geol. Survey Bull. 691, pp. 282-292, pl. 33, 1919.

⁹Harris, G. D., Oil and gas in Louisiana: U. S. Geol. Survey Bull. 429, pl. 12, 1910.

¹⁰Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, 1906.

week ending March 11, 1922. Since then the output has increased slightly.

STUDIES OF THE GEOLOGY OF THE FIELD

Field studies of the geologic structure were made in the summer of 1921 by W. W. Rubey, L. G. Mosburg, and H. W. Hoots, of the United States Geological Survey, and office studies were afterward made by K. C. Heald and W. W. Rubey. The primary purpose of these studies was to learn the conditions under which oil is most likely to occur in southern Arkansas. The investigation was afterward extended to ascertain the relations of the oil to the water in the strata for the information of the engineers of the Bureau of Mines, who were working in cooperation with the State.

Each oil-yielding district has its own peculiarities, and the rules that may guide prospecting in one area may not apply to another. The great number of test wells that have been drilled in southern Arkansas without finding oil in large quantity except in the El Dorado field show either that the oil pools in this region do not bear the same relations to anticlinal structure that they commonly bear elsewhere in the mid-Continent oil fields or that geologists have not learned how to locate the anticlines in this field by studying the surface formations. If the geologist is without definite rules to guide him in discovering oil pools, his usefulness is much less than it otherwise would be, and the operator must hunt for new pools blindly, so that his chances of success will be reduced and the average outlay for each pool he may find will be greatly increased. Random drilling has discovered many great oil fields, and persistent prospecting without geologic guidance would ultimately find every pool, just as a blindfolded man could find almost any object he sought if he sought long enough, but this is no reason why the blindfold should not be removed if it can be removed. One of the most effective aids in locating undiscovered pools is an accurate, thorough knowledge of the conditions in fields that have been developed, and any one who hopes to find new pools in southern Arkansas should study the El Dorado field and the fields to the south in Louisiana.

STRUCTURE OF THE FIELD

The geologic structure of the El Dorado field is unlike that of any other known field of similar size. The studies made covered only the northern part of the producing area, but there is no reason to think that the structure of the southern part is materially different. If the sand, clay, and gumbo could be stripped off the producing bed in the area covered by the map no large dome or great anticlinal arch would be seen. The surface of the oil sand is so nearly level that it might remind one of gently rolling prairies or of meadows made up in part of smoothly rounded knolls and swales or hollows whose slopes rise in even, sweeping curves. The evenness is interrupted by a number of low, almost vertical cliffs that mark faults where the rock has been broken and one side of

the break has risen from 1 to 30 feet above the other. There are probably a great many more of these breaks than are shown on the map. Almost without exception they trend northeastward, forming a sharp angle with the longer axis of the field, and most of the low folds that vary the flatness of the surface of the oil sands also trend northeastward.

The oil sand rises higher in sec. 1, T. 18 S., R. 16 W., than elsewhere in the part of the field that has been mapped. Not enough wells have been drilled in this part of the field to enable the geologist to work out its structure in detail, but it seems more nearly anticlinal than the narrow oil-yielding area that borders it on the northeast, east, and southeast. The few well records available indicate that in this part of the field there is a real dome on which the beds dip gently to the east and more abruptly to west and southwest. The wells on the dome yield gas and a little oil. Between this dome and the oil-yielding belt to the east there is a rather broad area over which the structure has not been worked out, so that the impression of flatness in that area given by the map is unjustified.

The structure in the area west and south of the gas-yielding dome, in sec. 1, is not known, but the few records that are available show that the oil sand there is fully as high as it is in the productive part of the oil field.

A study of well records in areas east and west of the El Dorado field shows that this field is not upon a pronounced regional uplift, although there may be a slight bulge or gentle arch in the El Dorado region. The strata dip gently to the east and southeast over most of southern Arkansas. If the El Dorado field is on a regional bulge or uplift there is a synclinal depression west or northwest of it. A flattening of the regional dip was detected but no true syncline. Furthermore, if the field were on an uplift the strata immediately east of it would probably show steeper dips than are common in this region, but no suggestion of such steep dips was found. The location of this field is therefore not controlled by the manner in which the rocks are folded. There is no true major anticline here, and the minor folds did not control the distribution of the oil, although the gas in this pool does tend to concentrate in arched or domed areas. The part of the field in which, as shown by the map, the structure is anticlinal lies in a sinuous belt that trends in general at little west of north through the center of sec. 31, T. 17 S., R. 15 W., including about 40 acres in the NW $\frac{1}{4}$ sec. 5, T. 18 S., R. 15 W., about 60 acres in the northeast corner of the same section, about 60 acres in the north-central part of sec. 8, T. 18 S., R. 15 W., and about 100 acres in the southwest corner of sec. 7, T. 18 S., R. 15 W. besides the gas-yielding dome in sec. 1, T. 18 S., R. 16 W. In no one of these areas are there oil wells that show productivity above the average or the freedom from water trouble that might be expected if the segregation of oil were controlled by anticlinal structure. If the dates of completion and of average decline in initial production are taken into con-

sideration in order to compensate for interference from adjacent producers, the wells in these anticlinal areas are perhaps a little above the average for the entire field, but this initial production is not higher than that of wells in adjoining synclinal areas.

On the other hand it can not be said that in this field there is no relation between geologic structure and the accumulation of oil, for structure includes both folds and faults, and the faults were probably influential in forming the pool. Nearly every area of high productivity in the oil-yielding belt here considered is traversed by one or more faults. A strip of richly productive territory does not border each fault shown on the map, but here and there along almost every fault there is a spot of unusual richness.

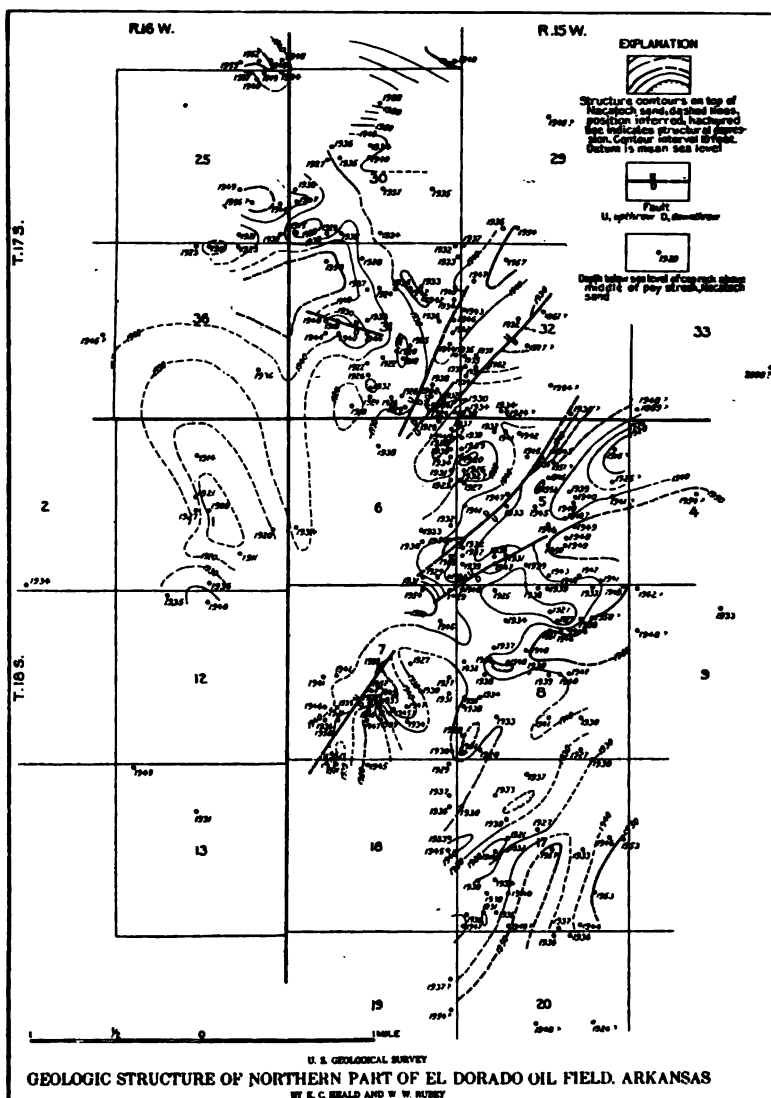
The direction and arrangement of the faults, and the shapes of the low folds that accompany some of them, probably indicate the presence of a large fault or zone of faulting in the beds deep below the Nacatoch sand, trending about N. 15° W. The structure shown by the oil sand there must have been produced by lateral movement along this fault, the strata east of it moving northward relative to the strata west of it.

HOW THE POOL WAS FORMED

The Marlbrook marl is believed to be the source of the oil in this field, and the accumulation of enough oil in the Nacatoch above the Marlbrook to form a commercial field is probably due to a happy association of a source of oil channels through which it could migrate, and a good reservoir bed. Oil was probably not formed everywhere in the Marlbrook, at least not in great volume, but in favored spots where it was laid down in shallow water and possibly raised above the sea from time to time, the conditions were right for the deposition and preservation of oil-forming matter. In any event, in some places the Marlbrook appears to have supplied large amounts of oil to the overlying Nacatoch sand, and in others, where the structure is seemingly quite as favorable, it has supplied little or none. At El Dorado the zone of faults crossed a productive area in the marl. The oil moved up along the fault planes and accumulated in the upper part of the Nacatoch sand. Pronounced anticlinal folding and faulting and a rich spot in the Marlbrook would together have produced ideal conditions for the accumulation of oil, and under such conditions the water trouble that has been the curse of the El Dorado field would not have appeared. The beds of sandstone lie so flat, however, that the oil they contain does not saturate them to any great thickness; but instead it is found in thin layers at the tops of several beds in the upper part of the Nacatoch, and the remaining parts of these beds are filled with salt water. The gas being more mobile than the oil has migrated to the more prominent domes and has excluded most of the oil and the water from certain thin beds of sandstone under the arched areas.

If the formations just above the Nacatoch had contained porous sand-

stones, the oil, as it moved upward along the fault planes, would probably have formed small pools in them, for the faults are not limited to



the beds below the top of the Nacatoch but certainly cut the Arkadelphia clays, although these beds contain few sands. The faults may cut also the Midway beds, although this supposition can not be definitely

verified by the well records, but no evidence was found to indicate that they cut the Wilcox.

Instead of originating in the Marlbrook the oil possibly may come from a much deeper formation, such as the Brownstown marl, the Eagle Ford shale, or the Lower Cretaceous beds. The depth of these formations below the Nacatoch is no obstacle to the migration of oil, for the faulting that cuts the Marlbrook must also cut them, and if it could furnish channels for upward migration from the Marlbrook to the Nacatoch it could almost as easily furnish channels for migration from the deeper beds. If the oil came from the Brownstown marl there may be chances of finding oil-reservoir beds in this formation or adjacent to it, and if it came from the Eagle Ford shale there is a good chance of obtaining it from the Blossom and Woodbine sands.

If the oil came from the Marlbrook marl, however, the chances of obtaining it from underlying formations are not exceptionally good, although these lower formations should not be utterly condemned. The records of other fields that draw oil from Upper Cretaceous formations prohibit such a blanket condemnation, for practically all fields that have yielded either oil or gas in notable amounts from the Nacatoch sand have yielded much greater amounts from either the Blossom or the Woodbine sands or both. The lack of anticlinal structure at El Dorado, however, offsets this favorable feature. Where oil has been found in the Blossom or the Woodbine there is either pronounced regional uplift or strong anticlinal folding. In the Caddo and De Soto-Red River districts there are both. In the El Dorado district there is neither. The conditions that are associated with oil pools in northern Louisiana, and to which the formation of those pools is presumably due, are therefore lacking here, and production from the deep beds can not be counted on. Nevertheless, the deep sands should be tested. The most promising locality for a deep test well, so far as the map shows, is the west side of the gas-yielding dome in sec. 1, T. 18 S., R. 16 W. The very center of the section seems to be a good location for such a test well, but as it is desirable to make a test for oil in the Nacatoch at a place west of the gas-bearing area, a location 800 feet west of the center of the section would probably be preferable.

OIL AND GAS ABOVE THE PRINCIPAL "PAY" SAND

A few wells in the El Dorado field have reported "showings" of oil or gas in beds in the Midway formation. A few reports that traces of oil have been found in these beds might be discredited, for enough oil to give a rainbow-colored film on the drilling water might accidentally get into a well, but showings of gas could not be thus explained, and it therefore seems evident that at least one bed in the Midway formation carries some oil and gas. This bed may lie about 1,150 feet below the surface over most of the field, or about 970 feet above the Nacatoch sand. A number of sands in a zone 200-300 feet thick may carry this

shallow oil. The wells in which it is reported do not lie on any of the faults that have been mapped or very near them, a fact which indicates that the oil probably did not rise along those faults.

Reported showings of oil or gas in a number of wells that have been drilled within a radius of 40 miles of the El Dorado field suggest that an oil-bearing sand may lie at the base of the Midway formation, tacular but less reliable wells that get oil from the underlying Nacatoch. No careful tests of these shallow beds seem to have been made in the field in spite of the very apparent need for such tests. Small water-free wells that would draw oil from a bed not more than 1,200 feet below the surface would probably yield greater net profits than the more spectacular but less reliable wells that yet oil from the underlying Nacatoch sand. Tests of the shallow sands should be made very carefully, for the gas in them is evidently under low pressure, and it would be easy for one to drill through a thin oil or gas bearing sand without suspecting its presence.

POSSIBLE EXTENSIONS OF THE FIELD

In the part of the field covered by this study the location of highly productive wells near faults suggests the desirability of drilling in the southwest corner of sec. 7, T. 18 S., R. 15 W., and in the adjoining territory in secs. 12 and 13, T. 18 S., R. 16 W. The field may probably also be extended in the SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec 32, T. 17 S., R. 15 W., and there seems to be no indication that the producing territory will not also include parts at least of the SW $\frac{1}{4}$ sec. 33, T. 17 S., R. 15 W., and of the NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 4, T. 18 S., R. 15 W. A well in the NW $\frac{1}{4}$ sec. 7, T. 18 S., R. 15 W., should yield either oil or gas, particularly in the eastern part of center of the N $\frac{1}{2}$ sec. 2, T. 18 S., R. 16 W., and the center of the N $\frac{1}{2}$ sec. 12, T. 18 S., R. 16 W.

A number of test wells should be drilled west of the gas-bearing area, for oil-bearing beds may possibly border the gas-bearing beds on the west and south as they do on the north and east. Suggested locations for test wells are the northeast corner of sec. 2, T. 18 S., R. 16 W., the center of the N $\frac{1}{2}$ sec. 2, T. 18 S., R. 16 W., and the center of the N $\frac{1}{2}$ sec. 12, T. 18 S., R. 16 W.

The extension of the field to the south of its present limits is to be expected, and determined prospecting to discover a northward extension is also justified by the peculiar type of structure. Operators should not accept a single dry hole as limiting the field in these directions. The producing territory at the present north margin of the field can probably be extended westward.

POSSIBILITY OF SIMILAR FIELDS ELSEWHERE IN SOUTHERN ARKANSAS

Parallel belts or faults separated by areas almost unfaulted may occur in southern Arkansas as they do elsewhere in the mid-Continent region, notably in northern Oklahoma and southern Kansas. If such a belt exists within a few miles of El Dorado the other favorable conditions

that combined to produce the El Dorado pool probably also exist there and a field much like the El Dorado field may be developed. Because of this probability the following suggestions are made:

1. If gas in volume is encountered in a wildcat well the search for oil should be continued by wells drilled east, northeast, or southwest of the gasser.
2. If oil is encountered in a wildcat well the extension of the oil-yielding areas should be sought by other wells drilled either north or south of the discovery well.
3. Gas pressure should be conserved by shutting in gas wells. The maintenance of high pressure will help to promote a greater extraction of oil and to prevent water trouble.

The chances for finding new fields are not limited to zones of faulting, for there are probably anticlines in southern Arkansas fully as strongly developed as those on which the Homer and Bellevue fields of Louisiana are located. Even if some of the conclusions here presented may be questioned other oil fields will no doubt sooner or later be discovered in southern Arkansas, for in view of the showings of oil obtained in widely scattered wells in this broad region it would be unreasonable to believe that there is only one place in it where the conditions are favorable to the formation of an oil pool.

DESCRIPTION OF THE PRODUCING BED

The Nacatoch sand in the El Dorado field is about 180 to 190 feet thick. The upper part is principally sand, but the formation also includes shaly sandstone and streaks of gumbo and shale. The lower part varies from slightly calcareous shale to hard limestone, although it generally contains some thin sandy layers.

The top of the sand is commonly marked by hard streaks called "rock" by the drillers. At some places these hard streaks are absent, and drillers who depend on them to indicate the top of the pay sand drilled deep into the sand before they realized that they had reached the oil-bearing bed. In fact the drillers of the Busey well, commonly considered the discovery well of the field, drilled through the bed that yields most of the oil produced from the surrounding wells without recognizing it and obtained oil from a lower pay streak in the sand.

There are at least three pay streaks in the upper part of the Nacatoch. No one of these streaks appears to extend through the field, but the middle one, which is about 40 feet below the top of the sand, is nearly continuous and yields most of the oil. Producing beds both higher and lower than the middle one have made good wells, but these other producing beds appear to be very patchy, or perhaps they have not been adequately tested, for comparatively few wells draw oil from them. The gas well drilled by the Constantine Refining Co., which was the real discovery well of the field, obtained its gas from a bed that lies about 40 feet below the bed which is yielding oil in wells to the east.

In all the pay streaks oil seems to be present only in the topmost few feet of the sand and is everywhere underlain by salt water. Salt water is also closely associated with the gas in the gas-yielding part of the field. Unless a well is completed with the utmost care this water flows from it with the oil and gas from the day it is completed until water flooding causes its abandonment. This water is much more difficult to combat than the water in most pools because there is no such thing in this field as "edge water," which is restricted to the margins of the producing area. So far as salt water is concerned this field may be said to be all "edge," and each well is a problem in itself.

There is no evidence that the Nacatoch is either thinner or more shaly near the edges of the field than elsewhere. It is undoubtedly much more shaly in some places than in others, but no relation between the yield of oil and the percentage of clean sand could be determined.

METHODS USED IN CONSTRUCTING THE MAP

The records of wells drilled with rotary tools are notoriously poor and afford very unreliable correlations. In the El Dorado field comparisons and correlations are particularly hard to make, because the top of the Nacatoch sand varies so little in elevation throughout the field and because no single bed can be easily and certainly recognized everywhere. The results presented on the map are admittedly open to challenge, but they represent very careful and painstaking work,—the best that can be done with the data available.

The correlation of the beds struck in different wells was first attempted solely by noting the relative positions of the beds of sandstone, limestone, chalk, and gypsum recorded by the drillers. The results of these correlations were not satisfactory. Next, the "rocks" recorded by the drillers were colored distinctively on the plotted well logs and were found to furnish a good tie between many of the wells. However, to make satisfactory correlations it was found necessary to assign characteristic symbols or colors to every term employed by the drillers. The record of the hardness was helpful. "Boulders" were in places distinctive. Some of the "pack sands" could be correlated between two or more wells. Shale and gumbo were distinguished, and although the usage of the drillers was not uniform their use of these terms furnished a valuable clue for many areas.

The work thus done permitted the recognition of small faults shown on the map. These faults would have been indicated by the evidence afforded by the oil sands, but this indication had to be confirmed in the upper part of the section. In a record of a well drilled across a normal fault a part of the stratigraphic section is missing, and conversely in a record of one drilled across a reverse fault a part of the section is repeated. In the parts of the map that are based on comparatively few well records the structure appears to be much smoother and simpler

than it is elsewhere, but if more records had been available these apparently simple areas would no doubt prove to be much more complex.

CHARACTER OF THE OIL

Detailed analyses of the oil from the El Dorado field, published by the United States Bureau of Mines in November, 1921, show that its gravity is about 34.2 Baumé and that it contains about 30 per cent of gasoline and naphtha and 13 per cent of kerosene, the remainder being gas oil and lubricating oil.

K. C. HEALD AND W. W. RUBEY

THE FOX OIL AND GAS FIELD, CARTER COUNTY, OKLA.

The Fox oil and gas field, located in T. 2 S., R. 3 W., Carter County, Oklahoma, includes sections 19, 20, 21, 22, 26, 27, 28, 29, 32, 33, 34, and 35. The area described is in the northwest corner of Carter County about 33 miles by road from Ardmore, the county seat.

The first producing well in the district, the No 1, W. B. Johnson, was completed as a gas well in the summer of 1916 by the Gypsy Oil Company. It is located in the southwest quarter of sec. 28, T. 2 S., R. 3 W. Its initial volume was 25 million cubic feet per day. The old Fox gas field was somewhat slow to develop and to date does not show the complete development of the proven territory. The discovery of oil producing sands within the gas area increased activities and in February, 1919, the Empire Gas and Fuel Company extended the field to the east by completing their No. 1 Davis, in the center of the SW¼ NE¼ of sec. 34, as an oil well having an initial production of 150 barrels per day. In July, 1920, the Humble Oil and Refining Company increased activities further in the eastern part of the field by completing their No. 2 Davis, in the NE¼ NE¼ of sec. 34, as an oil well with an initial production of 50 barrels daily. At this time, the price of crude oil was high and intensive development began in sec. 34 and 27. To date, the eastern part of the field has been better developed than the old gas field, due principally to the greater accumulation found.

The district is within the "Red Beds" plains province not far west of the Arbuckle plateau. Prominent escarpments mark the topography and are covered by thick growths of scrub or "jack" oak. The area is drained by Caddo Creek to the north of the field. The drainage is principally to the southeast. A very small percentage of the land is in cultivation. The roads are only fair.

The Fox anticline, like that of the Velma district farther to the northwest, has been known for some time and is a prominent and distinct structural feature. The major axis extends in an approximate northwest-southeast direction. The dips to the northwest are comparatively steeper than those to the southeast. The anticline has an approximate closure of 60 feet.

The rocks exposed are of Permian age probably the same group of sandstones and shales found in the Velma region to the northwest. Considerable slumpage has taken place and most of the exposures are greatly broken.

It is surprising to note the number of horizons producing in the district. The range of production over the entire area is from 150 to 2450 feet below the surface. The horizons are tabulated below, the range of each being only approximate and depending somewhat on structural conditions, dips, etc.

<i>Depth of Sand</i>	<i>PRODUCTION</i>	<i>Where Producing</i>
150-200 feet	Heavy Oil	31-2S-2W
230-300 "	" "	31-2S-2W
400-500 "	Gas	6-3S-2W
625-700 "	"	31-2S-2W, 6-3S-2W
875-900 "	"	31-2S-2W, 6-3S-2W, 26, 27, 35, 36, 2S-3W.
1450-1500 "	"	31-2S-2W
1530-1600 "	"	29-2S-3W, 31-2S-2W
1650-1750 "	Light Oil and Gas	29-2S-3W, 18-2S-2W
1790-1850 "	Gas	28-2S-3W
1880-1950 "	"	28, 29, 35, 2S-3W
1980-2050 "	"	28, 29, 2S-3W

Between 2050 and 2400 feet, some four sands are producing which are confusing when tabulated. These sands comprise the best producing zone, the chief sand being found between 2225 and 2380 feet. The initial productions from this sand range from 100 to 500 barrels per day. It is best developed in secs. 27, 34 and 33 of T. 2 S., R. 3 W.

A well in sec. 18, T. 2 S., R. 2 W., is producing from a sand at 2432 to 2488 feet below the surface. The well had an initial production of 60 barrels settling to 6 barrels per day.

The producing sands below 1500 feet are thought to be of Pennsylvanian age, probably belonging to the Glenn formation of Lower Pennsylvanian age.

The initial productions of oil wells in the district range from 6 to 500 barrels per day. The initial gas volumes, from 3 to 60 millions cubic feet per day. From a production report of March, 1922, the average daily production of the field was 3230 barrels from 58 oil wells. A greater part of this is from secs. 27 and 34.

Most of the oil has a gravity of between 34 and 36 Baume. The higher gravity comes from the deeper sands. The shallow wells produce oil varying from 24 to 28 degrees Baume. The Sinclair Pipe Line Co., handles most of the production.

The old Fox field is principally gas from some 33 wells. The Consumers Light and Power Co. of Ardmore contracts for the greater part of this and in turn supplies the city of Ardmore.

There have been 152 wells drilled, including both shallow and deep, of which 22 were dry. The dry hole percentage is approximately 14.

The cable tool method of drilling was used entirely in developing the gas field and not until the summer of 1920 was the rotary method introduced. The heavy gas pressure found in the upper sands make the cable tool method impracticable in the rapid development of the lower pay sands. The average cost of a rotary hole to a depth of 2200 feet is about \$16,000. The use of nitroglycerine in shooting the sands is not a practice as yet in the field as the horizons are sufficiently soft and open to give up the oil readily.

Renewed activity in the coming summer will further outline the field and important new developments are looked forward to with interest.

WILLIS STORM

OIL "SHOWING" IN GRANITE IN SOUTH AFRICA EXPLAINED¹

Showings of oil from a deep well drilled at N. W. Cape Province, South Africa, were investigated in 1921 by Dr. Wagner, Government geologist, whose findings should be of interest to all oil geologists.

The hole was bored with a diamond drill to a depth of about 4,610 feet. The upper 2,700 feet was through sediments mainly of the Dwyka series, from which a little gas was obtained. At about 2,700 feet the drill went into granite, and at 4,610 was in garnetiferous gneiss-granite. It was from this gneiss-granite that most of the "oil shows" came. These shows consisted of oil films on the drilling water and oily material in the slush from the well.

Doctor Wagner proceeded with painstaking care to prove the source of these oil showings. He was naturally convinced that they did not originate in the granitic rocks. A similar statement to that effect, however, would not have been convincing to the average oil operator. The geologists' belief that oil will not originate in granite is not nearly as convincing as the equally emphatic statement of a driller to the effect that he had actually obtained such oil when drilling in rocks classed by geologists as granite. There could be no question as to the actual existence of the oil shows. The source of the oil therefore had to be found.

Investigation showed that the three bottom joints of the drill stem were regularly greased with a mixture of tallow and anti-friction grease. There, then, was a possible source of the oil showings, and many geologists would have been satisfied to point this out and to make a definite, although unproven assertion, that this was undoubtedly the source of the oil. Dr. Wagner's thoroughness merits emulation. He learned how much grease was regularly used, and by figuring the speed of drilling found that it amounted to about 1½ pounds per foot per hole. He made

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observations on the temperature of the water that came from the hole, caught samples of the oily sludge from the well, and also took samples of the tallow and grease that were used for lubricating the rods.

Analysis of the anti-friction grease showed that, although it was principally mineral oil, it contained saponifiable matter with saponification value of 29.6. The tallow had saponification value of 201.5. The sample of sludge was extracted with the other, and the grease thus obtained was found to have saponification value of 141.5, showing that it was not mineral oil, and that beyond reasonable doubt it was derived from the mixture used for the lubricating.

A further proof of the origin of the greasy film on the water in the sludge pit was obtained by treating the mixture of the grease and the tallow with water about as hot as that coming from the hole. This test gave greasy films in all respects similar to those on the drilling water.

An interesting feature connected with the drilling of this well was the belief of the drillers, fostered by the occurrence of alternating hard and soft material, that they had encountered an oil sand. This alternation of hard and soft rock was due to the presence of steeply dipping gouge-filled fissures. One such fissure encountered at 4,520 feet was not passed out of until a depth of 4,596 feet had been reached, and the driller's belief that he had found sediments below the granite appears very excusable.

K. C. HEALD.

PROPERTIES OF TYPICAL CRUDE OILS FROM THE PRODUCING FIELDS OF KANSAS

The gravities fall between exceptionally narrow limits, 24 of the 27 samples having figures between 27° and 37°B. One, however, 19.4°, one 43.5°, and the third exception, barely over 37°. The average for all samples is 31.8°.

Sulphur contents vary between 0.12 and 0.66 per cent, although the majority of the samples range between the limits 0.20 and 0.40 per cent. The viscosity and pour tests also show only a moderate variation in this respect.

The results of greatest practical significance are those for gasoline and naphtha content, and for carbon residues of the distillation residuums. In the majority of samples the gasoline-naphtha content ranged between 10 and 30 per cent, averaging 22.3 per cent. These figures are in general, more favorable than are usually attributed to Kansas crudes. This seeming discrepancy arises from the fact that in the survey, gasoline and naphtha are grouped together, taking into account only the end point of the cut. The results, therefore, do not indicate whether the material is suitable for motor fuel or requires blending with natural-gas gasoline. However, it was shown that most of the Kansas crudes have relatively high initial boiling points and relatively small percentages of constituents distilling below 100°C (212°F). The

relatively high gravities of the gasoline-naphtha fractions also indicate that blending is necessary if the material is to be used as motor fuel.

In some of the Kansas fields, the oil wells are practically devoid of natural gas, and it was noted that the oils from these fields have, as a rule, unusually high boiling points.

With regard to cylinder stocks and similar lubricating oils, the results of the survey indicate that the average Kansas crude is not favorable material for this purpose. This opinion is based on the fact that the carbon residue from the distillation is for most of the samples more than 8 per cent, whereas experience shows that the best crude oils for this purpose have carbon residues not in excess of 3 per cent and in general should not exceed 6 per cent.

With regard to classification on the basis of the proportionate content of different groups of hydrocarbons, the gravity and viscosity results indicate that the Kansas crudes are intermediate between those of "paraffin base" type, represented by Pennsylvania and West Virginia crudes, and those of the "naphthene base" type, as Gulf Coast and California petroleum. The Kansas crudes are remarkably uniform in their moderate range of variation in viscosity and gravity, especially when contrasted with oils from the Rocky Mountain district, and evidently maintain the same proportional balance between naphthene and paraffin hydrocarbons throughout the entire distillation range.

Copies of the complete serial on the Kansas crudes with tables of distillation results may be obtained on request from the Director of the Bureau of Mines, Washington, D. C.

E. W. DEAN, M. B. COOK AND A. D. BAUER.

THE HAYNESVILLE, LOUISIANA, FIELD

Since the recent westward extension of the Haynesville (Louisiana) field by the W. H. C. Oil Company's Shaw No. 1, an 1,800 barrel well in sec. 18, T. 23 N., R. 8 W., and the Levert Oil & Gas Company's Hunt No. 1, a 300 barrel well in sec. 7, T. 23 N., R. 8 W., there have been several interesting developments. It appears that some of these western wells have been drilling too far into the sand and considerable quantities of basic sediment, and salt water have developed. The increase in gas westward may account for some of this basic sediment. The Standard Oil Company's Shaw No. 1, in sec. 19, T. 23 N., R. 8 W., came in at the rate of 7,000 barrels a day, but in a few days was making 70 percent basic sediment although still making 2,500 barrels of fluid. In this well the top of the producing sand was 2,507 feet below sea level. In several other recently drilled adjoining wells, considerable quantities of basic sediments and salt water have developed and it has been necessary to plug back.

The suggestion is again made that since 2,500 feet below sea level seems generally to mark the salt water line in the main part of the field, that great care be taken in drilling in wells in which the top of the

sand lies lower than 2,490 feet below the sea, lest salt water and basic sediment be encountered.

The thickness of the sand actually producing the oil has been greatly overestimated in many cases and has led to deep drilling into the sand. The average thickness of pay sand is not more than 8 or 10 feet, although a number of wells in the eastern part of the field have had up to 15 or 16 feet of pay sand.

The policy of penetrating from 30 to 50 feet of sand in the older part of the field has not been advantageous since in many cases it has brought in salt water, and later increased the basic sediment content of the oil. and has also exposed a greater column of sand, mostly very fine, which has heaved in and abruptly cut off large producing wells, thus accounting to some extent for the sudden decrease in the field's production. In addition the deeper drilled wells will first feel the detrimental effects of the advance of the salt water as the oil is drained off.

Development to date has definitely limited the field on the south, southeast, southwest, and northeast. From the curve of the structure contours the limit of the western part of the field may be defined in the eastern part of sec. 13, T. 23 N., R. 9 W., Webster Parish, Louisiana. On the east the sand is gradually sloping toward the salt water line but is still about 35 feet above it stratigraphically.

The slope of the sand northward is gentle but suggests a rapidly approaching limit.

Within the past few days some oil has been found in the Red Rock Oil Company's well in sec. 10, T. 23 N., R. 9 W., $3\frac{1}{4}$ miles northwest of the west edge of the Haynesville field. The sand was struck at 2492 feet below sea and commercial oil is probable. Whether the Red Rock well will tie up with the Haynesville field is a matter of doubt, but that it will connect with the Sinclair Oil Company's Mayfield well in sec. 20, T. 23 N., R. 9 W., 3 miles southwest, is probable.

L. P. TEAS.

May 4th, 1922, Shreveport, La.

A METHOD OF DISTINGUISHING FUSED CORES¹

Several letters have appeared in the Bulletin recently, describing specimens of sediments which had been fused by the friction of the core barrel used in taking cores. A number of such fused cores have been submitted to the U. S. Geological Survey during the past year with the request that they be examined to ascertain if they were igneous rocks. Thus it is evident that fused specimens are frequently mistaken for igneous rocks. Fusion by the friction of the core barrel is a frequent occurrence, and with the increasing use of the rotary drill the

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question of the presence of igneous material in the rocks penetrated is likely to recur again and again.

Pure sands are very infusible, but shales and especially arkoses and tuffs are relatively fusible, and the partly fused core from such a rock superficially resembles a basalt. Microscopically the habit, composition, and mineral relationships are strikingly different from those seen in a basalt or in fact any igneous rock. A thin section of such material under a microscope shows a ground-mass of brown glass enclosing grains of quartz and feldspar and many small black opaque particles.

Ferromagnesian minerals form a conspicuous part of basaltic rocks, but they are practically absent in fused sediments. Their small resistance to weathering often results in their partial elimination from sediments, and where they are present their great fusibility results in their complete solution in the glass. The feldspars give a superficial resemblance to an igneous rock, but the grains almost never have crystal outlines. Calcic and alkalic feldspars are frequently found in association, as they would not be in an igneous rock. Basaltic rocks seldom contain any quartz, but in the fused cores quartz is abundant and is angular in outline, as it would not be in an igneous rock. The small black opaque grains are fragments of iron and steel derived from the drilling tools. Iron is an extremely rare element in terrestrial rocks and is unknown in association with quartz. The occurrence of iron in the fused cores is the most fundamental and conspicuous difference between them and igneous rocks. If the presence of iron can be established, it constitutes practically conclusive evidence that the material containing it is not igneous in origin. As all fused cores examined contained metallic iron, its presence can be used as criteria as to the origin of the rock.

It is not always convenient to await determination till the specimen can be examined by a petrologist, and a method that could be applied in the field by geologists or drillers alike would no doubt interest many oil men. This letter is written to point out that such a simple field test requiring practically no apparatus is available. The method is as follows: Pound some of the material from the core to a fine powder taking care that no steel fragments become mixed with it. Spread on a piece of paper and separate any magnetic material with a small horseshoe magnet. If a magnet is not available, the crushed rock can be panned and the heavy materials concentrated. Transfer the concentrate to a small glass or porcelain dish, add a little water and a few small crystals of copper sulphate (blue vitriol). If iron is present, it will within a few minutes become coated with copper and assume the characteristic metallic copper color. A specimen of the uncrushed rock can be dipped in the copper sulphate solution and the disseminated grains will become copper coated, but they are usually small and inconspicuous and a good hand lens will be required for their identification. The copper coating will become dull, if left in the solution too long, but will again become bright on being rubbed briskly. This formation of a copper

coat gives an almost certain test for metallic iron, and, if iron is present, it affords practically conclusive evidence that the rock is not igneous. If the test is negative, it is not quite so conclusive that the rock is igneous, and it may be necessary to have it examined microscopically before finally concluding as to its origin.

CLARENCE S. ROSS.

OIL IN MIDDLE ORDOVICIAN IN INDIANA¹

The search for oil in the sub-Trenton formations in Indiana is discussed by W. N. Logan, State Geologist of Indiana, in the *Oil News* for March 20, 1922, pages 60-61. Details are given regarding a number of wells that have been sunk to the sub-Trenton formations in the state and showings of oil that have been encountered in the St. Peter sandstone of Middle Ordovician age are recorded. The three most significant tests are probably those cited below: :

"A well drilled recently in Marion County encountered a 30-foot stratum of sand in the upper St. Peter which contained a heavy asphaltic oil. At this point the surface of the Trenton is about 300 feet below the sea level.

In Decatur County a deep well has already passed through the St. Peter into the lower Magnesian. Some gas was found in the upper part of the St. Peter and a porous dolomitic limestone was encountered in the lower Magnesian.

A sub-Trenton test in Clark County, in the southern part of Indiana, encountered a fine white sand in the upper St. Peter which showed slight indications of oil according to samples submitted to the writer."

No other showings have been reported, but if the identification of the formations is unquestionable, these three wells show that the Middle Ordovician of Indiana must be regarded as a possible source of oil and gas. This is all the more true because, so far as Professor Logan is aware, these tests were drilled "without knowledge of their position in relation to the minor structural conditions."

This article by Logan is a warning to oil geologists that it is neither safe nor good geology to place the lower limit of possible oil production in the Trenton or equivalent horizons of Ordovician age. This holds true not only in the Indiana-Ohio district but also in Illinois, Missouri, and the northern Mid-Continent field.

K. C. HEALD.

IS THE STAPLETON PAY OF THE EL DORADO FIELD, BUTLER COUNTY, KANSAS, ORDOVICIAN OR MISSISSIPPIAN IN AGE?

The deep, or Stapleton, pay zone of the El Dorado field of Kansas is reported by Aurin, Clark, and Trager¹ to be composed principally of limestones of Ordovician age with locally a higher sand-

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stone which they tentatively correlated with the Tyner formation, also of Ordovician age. This sandstone is described by them as a thin veneer separating the Ordovician limestones from the overlying Pennsylvanian shale.

The present writer in his investigation of the El Dorado field² obtained evidence which is contrary to that described above, and hence his interpretation of the limestone portion of the Stapleton pay as of Mississippian age differs radically from that of Aurin, Clark, and Trager. Stated briefly, the evidence described in the report on the El Dorado field shows that in the Stapleton pay zone the limestone overlies the sandstone and that the deeper rocks continue to be sandy, which is exactly opposite to that described by Aurin, Clark, and Trager. Either the present writer or Aurin, Clark, and Trager have drawn conclusions from mistaken evidence.

In view of this contradiction of evidence presented in the two publications, the present writer wishes to bring attention to the information upon which his conclusions were based and to reiterate that this evidence indicates the Mississippian age of the limestone that forms the major part of the Stapleton pay zone.

In the El Dorado report the Stapleton pay is described as a zone of porous rock at the top of an eroded surface of pre-Pennsylvanian formations. In some wells the pay rock is entirely a cherty dolomitic limestone. In other wells the pay rock consists entirely of a quartzose sand. In still other wells a small amount of the limestone is first penetrated and the drill then passes into the sandstone. The definite statement is made on page 37 of the report, and this statement is still valid so far as the writer is aware, that in wells where both limestone and sandstone constitute the pay, the limestone overlies the sandstone.

Some of the evidence covering this point on which the present writer made his interpretation is given in detail on pp. 33 and 34 of his report. Equally definite evidence was found in cuttings from three or four additional wells. The fact that this limestone is found to be thick in some places, thin at other places, and completely missing at still other places, indicated to the writer that the limestone was a remnant of an eroded formation left on the top of the El Dorado anticline after this fold had been subjected to erosion prior to Cherokee time. Its cherty nature and the correlation evidence given graphically on plate VI of the report, seemed to indicate, although it did not conclusively prove, its Boone age. This correlation evidence would need be more detailed to prove conclusively its Boone age, and even more detailed to disprove it

¹Aurin, F. L., Clark, G. C., and Trager, A. E., Notes on the sub-surface pre-Pennsylvania stratigraphy of the northern mid-continent oil fields: *Am. Assoc. Petroleum Geologists Bulletin*, vol. 5, No. 2, pp. 143-144, 1921.

²Fath, A. E., *Geology of the ElDorado oil and gas field, Butler County, Kansas: State Geol. Survey of Kansas Bull. 7, 1921.*

in favor of the more radical conclusion reached by Aurin, Clark, and Trager that the Boone is completely beveled and present only low down on the flanks of the El Dorado anticline. In view of the present difference of opinion, it is to be regretted that the details of their evidence covering this point were not published in order that its value could be appraised. An additional point that should be noted is that the limestone of the Stapleton pay is almost entirely cherty dolomitic limestone, whereas the Ordovician limestone with which Aurin, Clark, and Trager have correlated it is found in most places other than the El Dorado field as a siliceous limestone. Until contrary paleontologic evidence is obtained or until sufficiently detailed well log evidence is published to show that the Boone is completely beveled and present only low down on the El Dorado anticline, there is no reason for concluding that the limestone of the Stapleton pay is other than the Boone of Mississippian age.

The age of the underlying sand, which in places constitutes a part and in other places constitutes the whole of the Stapleton pay, was considered in the El Dorado report as of undetermined but pre-Boone age. This sand, on the basis of the evidence presented by Aurin, Clark, and Trager, could, tentatively, be considered the top part of the formatoin which they consider to be the Tyner of Ordovician age.

A. E. FATH

OIL WELL IN SCOTLAND

The D'Arcy well 12 miles southeast of Edinburgh, Scotland, came in May 8th flowing high grade oil from a sand 1,810 to 1,820 feet. The sand has not been drilled through. This is the last test made by S. Pearson & Son for the British Government. It is located near the crest of an anticline. The production is estimated as several hundred barrels but the hole was full of cavings and 6 inch liner was set a 1,765 feet in an 8 inch hole. Production comes from the Calciferous series. The oil is slightly lower gravity than that at Hardstoft, England, but contains more paraffin wax.

This well is 300 miles north of the Hardstoft well in Derbyshire which is still flowing about 3 barrels a day. Other tests have been abandoned: 7 in Derbyshire, 2 in Straffordshire and one at West Calder, 19 miles southwest of Edinburgh in the oil shale country. The West Calder well was not drilled deep enough to test the formations underlying the oil shales.

SIDNEY POWERS.

DISCUSSION

THE NECESSITY FOR ENGINEERING IN DEVELOPING OIL AND GAS PROPERTIES

Much has been said and written in the past ten years regarding the need of more scientific methods of drilling wells and the extraction of oil and gas. We have all recognized that the geologists or petroleum engineers are too far apart from the driller and the practical operator. Anyone familiar with the petroleum industry knows that it has suffered for lack of practical application of engineering principles and that there is much careless and inefficient development work being done, even at the present time. The fact is that we are making no particular progress in bringing our practical work up to a higher engineering level; we are comparatively at a standstill and will remain at a standstill until we are thoroughly awake to the situation.

We are accused by our British competitors of drilling our wells in a very slipshod manner; they tell us that we pass up many important oil and gas shows because of our present methods. Unfortunately, we are, generally speaking, guilty of this practice and we should all begin a campaign that will give better results.

The petroleum geologist has made rapid strides in the past ten years. Though handicapped by poor log records, obtained from the practical end, he has, nevertheless forged ahead and is today far in the lead of the driller. Had the latter kept abreast of the geologist, it is safe to say that the oil industry would be much farther along the road than it now is. Any geologist, at all familiar with log records will bear out the truth of this assertion.

How then can we improve the practical end of the industry and bring it up to where it belongs? We are, in the future going to do deep drilling in many parts of the United States and we may expect deep production. Is it not high time for us to consider more seriously the necessity for engineering in exploitation and production work?

Take the case of the mining engineer. He is a graduate of some mining college, who has a working knowledge of Geology, Mechanical Engineering, Electrical Engineering, Chemistry and Civil Engineering. The important thing is that he gets underground and learns from practical experience the work of timbering, mucking machine and hand drilling etc. In fact, he goes to school at the mine plant for several years after having been graduated and until he does know the practical end, he is not properly a mining engineer.

This is exactly the sort of man we need to go into our oil fields and who will stay there, on the derrick floor and on the property until he is fully capable of filling any job from "roughneck" to driller. This practical experience should not be less than three years but when this time is completed, we will hear from such men. They will apply their theoretical engineering knowledge to the job and the job will be the gainer.

We have too few of these men in the industry. How many engineers of your acquaintance can hold down a job as driller? The tendency of engineers and geologists has been and is, to dodge this sort of work and by the way, a good practical working knowledge of drilling wells and producing wells would not come amiss for the geologist, either. These remarks apply particularly to rotary drilling. Fortunately, standard drilling is better done but there is room for improvement in the latter, too.

In addition to the practically educated petroleum engineer, there should be a decided and united effort to reach the practical driller and to educate him as far as possible. The writer recognizes the fact only too well, that many managers who are in control of properties, are badly in need of an engineering education themselves. There is no excuse, for instance, for a driller to turn in a drilling report showing "rock" or "hard rock" or "soft streak" as we so frequently note. Neither is there any excuse for the manager to accept such a report. Both men should be made to realize the importance of accurate and complete records. The writer recalls that a certain big company operating in the Ranger, Texas field did not have the casing records or logs of a number of wells which were drilled. When these wells were gone into later, the clean out crews had not the faintest idea of the casing or depths of pay. Such carelessness of course is inexcusable but, unfortunately, it has been too often the case.

It is not here intended to call attention specifically to numbers of other details where improvement is vitally necessary but rather to point out a common sense way to educate the men who need it so badly.

In the first place, our young graduates should go right into the oil field and stay there until they actually know the drilling and producing end of the business. They are the managers of the future and we need many of them right now. We need engineers who have specialized in Electrical, Mechanical and Civil Engineering and who are willing to continue through to a thorough education in all phases of the business of producing oil. Their presence in the industry will mean much and we will suffer without their services.

As regards the present driller, many have not even an high school education, but at the same time there are many shrewd men in their ranks, who can be taught. For their benefit, a series of lectures could be undertaken at various centers and the companies employing them could well afford to pay their expenses while they are getting the benefits of the lectures. These would be given by men qualified by experience and knowledge to discuss fully the particular subjects allotted to them. The lectures could be given on Elementary Geology, Practical Drilling, under the heads of mud laden fluids, cementing, core barreling, testing formations, controlling oil or gas wells and collapsing pressures of casings, the proper care and use of machinery, proper firing of boilers and the efficient producing of oil. Such a series of lectures could be given

in three days and each lecturer would of course prepare charts, blue prints, etc., to illustrate fully every important point. The men could take notes which could be supplemented later by copies of the lecture and it would be the duty of the manager of the company to see that they either profited thereby or else were dropped from the pay rolls.

It is true that many drillers have no use for such information but there is no doubt but that, under proper conditions, they could be shown the necessity for a better understanding of the duties required of them. The only way to get accurate records is to educate the man who makes them. They should be either educated or eliminated from the industry as unsafe drillers.

BEN K. STROUD.

IS IT INJURIOUS TO CLOSE IN AN OIL WELL?¹

Unqualified assertions that it is unsafe and unwise to shut in producing oil wells are frequently heard. Still more often the inference is made that such a procedure may be injurious, and that it is undesirable. The claim that if small wells are once abandoned they will not "come back" was advanced as one of the strongest arguments for a tariff on oil, during the period when Mid-Continent oil was selling for little more than half its present price. The oil-field strike in the fields of San Joaquin Valley, Calif., during September and October, 1921, provided an opportunity to observe how facts agree with theories. This strike resulted in the total cessation of operations for a month or more on a number of properties, and in partial paralysis of others. The effects of the shut-down in the various fields of the San Joaquin Valley are discussed by C. C. Thomas, E. Huguenin and R. M. Barnes in the chapter for February, 1922, of the Seventh Annual Report of the State Oil and Gas Supervisor of California.

The statistics and facts presented by the observers mentioned above leave no room to doubt that as a whole the shut-down was beneficial to the oil wells. A few wells that had been pumping a mixture of oil and water before they were closed in yielded nothing but water for a few days after they were reopened, but persistent pumping restored them to their original productivity. On the other hand, some wells that yielded nothing but water before they were shut in, and that were pumped merely to keep the general water level low, yielded some oil after they were reopened. Other wells that had yielded a mixture of oil and water before the shut-down yielded nothing but clean oil for a short time after pumping was resumed. However, the showings made by groups of wells were much more significant than those of individual wells. These wells showed a general increase both in total oil and total water produced per well, and also an increase in the percentage of oil to water.

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On some leases there was a great increase in the yield of oil and a decrease in the yield of water.

In only one field was a decided decrease in oil output noted, and this was for only a portion of the field. In the area of high water production in the old Kern River field some difficulty was experienced in bringing the wells back to normal productivity. However, even in this area the period of subnormal output lasted only 20 to 30 days. Compensating it, the wells in the area of low water production in this field showed phenomenal gains in output, and two months after the wells had been reopened they were still yielding more than at the time they were shut down.

The conclusions regarding the Coalinga field voiced by R. M. Barnes seem to be applicable to all the fields affected by the strike. "From the data on hand it can be concluded that no material change in water conditions resulted to underground deposits because of the cessation of producing operations. . . . The ultimate recoverable quantity of oil has not been decreased by the shutting in of wells, and production statistics indicate that the production, which was merely postponed during the period of the shut-down, will be recovered in many cases within a few months after resumption of pumping because of consistent above-normal production which many wells are showing."

K. C. HEALD.

REVIEWS AND NEW PUBLICATIONS

OIL PROSPECTING IN MICHIGAN

In an article published in the *Michigan Manufacturer and Financial Record* of Apr. 22, 1922, Mr. R. A. Smith, State Geologist, presents a number of interesting facts relating to the search for oil in Michigan. Among other things he says:

"The bed rocks are covered nearly everywhere in the State by deposits of sand, gravel and clay, which make it difficult or impossible in most places to tell where the anticlines are in advance of drilling.

"There are anticlines at Port Huron, Saginaw and Seul Choix Point (Schoolcraft County). The first two yielded oil in small quantities, and with more complete exploration larger quantities of oil might be found. Anticline-like structures appear to be present at Allegan, near Niles; at Muskegon, and Manistee, on Little Traverse Bay; along Detroit, and in Monroe County. The oil found in the wells drilled near Deerfield appears to be on a pronounced anticline or a terrace-like fold, but its form, direction or size is as yet uncertain.

"Drilling operations are now going on in several places, and Michigan in the next few weeks or months may become a real producer of oil. In fact there is a well near Deerfield, in Monroe County, which is said to be yielding about four barrels of oil a day—very small, it is true, but the next well may be a much larger one. The oil formation is the same as in the famous Lima and Findlay oil fields of northwestern Ohio, hence there are good possibilities worthy of thorough testing, especially as a favorable "structure" for oil appears to be present.

"Another well near Mt. Clemens is down over 3,500 feet, but unfortunately it has a string of tools in the bottom of the hole. If these are gotten out it would probably take but a few days to reach the supposed oil sands. A third well, near Brown City, Lapeer County, is making rapid progress, and in a few weeks should be down to the oil formation. A fourth well is being drilled near Dey's Lake, Jackson County, to a depth of over 3,000 feet. It is already down more than 1,700 feet. Another well is soon to be started near Peck, Sanilac County, as soon as the weather permits.

"Another well is to be started on Paul Choix Point, about 15 miles east of Manistique. The different concerns are planning several tests in the vicinity of Manistee, where showings of oil were struck in several old wells drilled for salt. One of the wells spouted oil and water 150 feet in the air. All of these places have possibilities of oil.

"In 1914 oil was struck not only in several wells at Saginaw, but in no less than four sands. The quantity, however, was too small for profitable operations. The oil from one well was exceptionally high grade, equal in gravity to the average Pennsylvania crude. Likewise at Allengan oil was struck in several wells, but again in too small quantities. Two old salt wells at Muskegon have been seeping oil for years,

one of them nearly a barrel a week. The crude oil was used by a manufacturing concern for oiling its machinery. Several years ago oil was struck in small quantities in a number of wells in southwestern Michigan, but not in commercial amounts.

"With so many showings of oil it is reasonable to expect that somewhere in the State oil will be found in commercial quantities. Just where this will be no one can say in advance of the drill. Probably the unbroken chain of failures, however, is not wholly due to unfavorable geological conditions in the State as a whole, but in part to misguided, haphazard and crass-brained exploration. With more intelligent development it is very possible that the State would have been a producer of oil long ago."

A TREATISE ON PETROLEUM

SIR BOVERTON REDWOOD

The Fourth Edition of the above Treatise is published by J. B. Lippincott Company, at a cost of \$39.00, postage extra (mailing weight 9 lbs.). The three volumes consist of 364, 375 and 612 pages, respectively, and are illustrated by maps of various portions of the world including a map of the United States in four sections—scale: 1—2,500,000. Owing to the death of Sir Boverton Redwood as the revised edition was going to press, the work has been edited by Sir F. W. Black. The section of twenty-four pages dealing with the United States, has been written by geologists of the U. S. Geological Survey with special attention from O. B. Hopkins. The first volume comprises an historical account of the petroleum industry, the distribution of petroleum, its physical and chemical purpose, and its origin. Volume 2, treats of the production and refining of petroleum, shale oil and allied industries and with the transport, storage and distribution of petroleum. Volume 3 describes the testing of petroleum and allied products, their uses, regulations regarding their testing, storage and transport and statistics of production. This is followed by a bibliography of 8,804 titles and an index of 35 pages. This monographic work is indispensable to any one interested in the occurrence and mining of petroleum outside of the United States and the bibliography is one of the most complete dealing with petroleum and its products.

S. POWERS.

MUD LADEN FLUIDS AND TABLES ON SPECIFIC GRAVITIES AND COLLAPSING PRESSURES

BEN K. STROUD

Technical paper No. 1 of the Department of Conservation, State of Louisiana, discusses in 14 pages the use of mud laden fluid and the collapsing pressure of casing. The pamphlet may be obtained free in Shreveport, Louisiana.

**PRELIMINARY REPORT ON PROPOSED PIPELINE FROM THE
MONROE GAS FIELD TO NEW ORLEANS****BEN K. STROUD and F. T. PAYNE**

The Department of Conservation, State of Louisiana, has issued a mimeograph pamphlet 8½x10½ in size, discussing a proposed pipeline and giving estimates of the available gas supply in each of the gas fields of Louisiana. The description of wells in these fields and the estimates of recoverable gas are of great value as a reference. The 38 pages of text are followed by charts and by a map of Louisiana, scale of 12 miles to the inch, showing the location of the gas fields. This publication may be obtained free at Shreveport, Louisiana.

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- Beal, C. H. Essential factors in valuation of oil properties. *Trans. Am. Inst. Min. and Met. Eng.*, vol. 65, 1921, pp. 344-352. Discusses the following important factors: (1) amount of oil the property will produce; (2) amount of money this oil will bring (based on the future prices of oil). (3) development and production costs; (4) rate of interest on the investment; (5) the retirement or amortization of invested capital; and (6) the salvage or "scrap" value of equipment when the property is exhausted.
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- Case, J. B. Report on Huntington Beach oil field, Orange County, California, with special reference to lack of definite subsurface information after eighteen months of drilling activity. Summary of operations, California oil fields. Monthly chapter, Seventh Annual Report of the State Oil and Gas Supervisor, November, 1921, pp. 8-43. Deals with the various phases and peculiarities of development of this field, which led to its present condition, and shows some of the causes of lack of information on underground conditions. Data used are as of August 13, 1921.
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- Hill, H. H. Possibilities of chemical research in producing branch of oil industry. *Oil Weekly*, vol. 24, Jan. 21, 1922, pp. 15-16. Discusses the various problems in oil production which may be solved by chemical research, such as the study of oil-field waters, oil field emulsions, corrosion of pipe, and cementing materials.
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- Kelly, R. W. Accident prevention in the Associated Oil Company. *Min. and Oil. Bull.* vol. 7, Oct. 1921, pp. 657-660, 668. Tells of organized safety work of this company and its results.

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- Knapp, Arthur. Rock classification from the oil-driller's standpoint. *Trans. Am. Inst. Min. and Met. Eng.*, vol. 65, 1921, pp. 424-429. Defines terms used by drillers and gives a tabulated summary of rock classification, showing general classes, rotary drillers' terms, cable drillers' terms, use in rotary and cable-tool drilling systems, and technical equivalents.
- Matler, H. A. The Alexander "gasser." *Bulletin Union Oil Company of California*, vol. 1, Feb. 1922, pp. 3-6. Account of a gas blow-out near Santa Fe Springs, Calif. including discussion of the origin of natural gas and petroleum and the cause of such outbursts.
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- Munger, E. J. New boon to rotary found. *Petroleum Age*, vol. 8, Nov. 15, 1921, pp. 19-20. Tells of the use in California fields of precipitated calcium carbonate from sugar factories for mixing with rotary mud.
- National Petroleum News. How one of the fiercest fires in history of Mexico was extinguished. Vol. 14, Jan. 18, 1922, pp. 65-66, 69. Account of the extinguishing of the No. 4 Toteco well, of the Mexican Gulf Oil Company, in the southern district of Mexico.
- National Petroleum News. New type segmental insulation proves successful in practice. Vol. 13, Nov. 9, 1921, pp. 29-30. Describes an entirely new type of segmental still and oil-field boiler insulation with the added advantage of not absorbing water, oil, or vapors, developed in Houston, Texas.
- Oil Weekly*. Drilling costs in various fields. Vol. 24, Jan. 21, 1922, pp. 54, 56, 60. Gives average costs as of December 15, 1921, for wells in California, Mexico, Oklahoma, Kansas, Texas and Arkansas.
- Oil Weekly*. New device for flowing wells being used in California. Vol. 24, Jan. 21, 1922, p. 66. Describes the Putman pneumatic lift.
- Oil Weekly*. Trinidad wells to have longer life. Vol. 24, Jan. 21, 1922, pp. 28, 32. Tells of the successful use of screen and the handling of tools under heavy pressure through an arrangement of stuffing boxes in a Trinidad well.
- Oliver, Earl. Appraisal of oil properties. *Trans. Am. Inst. Min. and Met. Eng.*, vol. 65, 1921, pp. 353-360; discussion, pp. 361-364.
- Pepperberg, L. J. Leaks in the oil fields. *Oil Weekly*, vol. 24, Jan. 21, 1922, pp. 21-22, 24, 34. On the importance of using economical and efficient methods in oil fields.
- Rice, R. H. Estimating natural gas reserves. *Oil and Gas Jour.*, vol. 20, Sept. 30, 1921, pp. 80, 93-94; Oct. 7, pp. 90-91. Discusses the subject under the following heads: Importance of knowing the quantity of reserve gas. The available data. The use of the data. Apparent variations from Boyle's law in the history of natural gas pools.
- Ruedemann, Paul. Comparative barrel-day values. *Oil and Gas Jour.*

- vol. 20, Oct. 28, 1921, p. 81. Explains method used in placing valuations on properties for taxation purposes.
- Suman, J. R. Reverse return system of rotary drilling. *Oil Weekly*, vol. 24, Jan. 21, 1922, pp. 42, 44, 46. Explains principles of a new system of rotary drilling recently developed in the Gulf Coast region in the work of exploration for sulphur, pointing out its adaptability in certain phases of petroleum exploration.
- Veatch, A. C. Petroleum resources of Great Britain. *Trans. Am. Inst. Min. and Met. Eng.*, vol. 65, 1921, pp. 3-6; discussion, pp. 6-7 Gives status of oil development in England to date, future commercial prospects, and characteristics of the oil from the Hardstoft well.
- Whitney, R. H. Old wells of Oklahoma and Kansas. *Oil and Gas Jour.*, vol. 20, Oct. 7, 1921, pp. 82-85. Reviews records of many of the old wells of these States which indicate the lasting qualities of certain sands.

THE ASSOCIATION ROUND TABLE

PROFESSIONAL ETHICS

The subject of professional ethics or morals assumes that there are, or ought to be, standards of conduct. But obviously there can be no authority in such a matter except that which the profession sets up for itself as a result of consensus of opinion of men of judgment and of experience. There are analogies from the professions of medicine and law, and there are such standards as the U. S. Geological Survey and some State Surveys try to maintain regarding the private use or non-use of information gained at public expense. But, broadly speaking, the problems are peculiar to the profession and hence analogies do not cover them; and furthermore, some of the problems do not arise at all in the public services, but are met only in private practice or employment. The young man in the profession may have had no advice and little experience to guide him away from bad practices. A few older men may feel that sentiment is too ill-defined to bring serious embarrassment as a result of any conduct, or that no professional obligation ought to count against temporary self-interest. Apparently evils have crept in and assumed such proportions that this association is seriously trying to see whether professional ethics can be crystallized into a code of conduct.

Any discussion of this problem will bring out differences of opinion as to where the emphasis should be placed, and indeed as to whether specific practices merit disapproval, but perhaps there will be sufficient agreement for the statement or the adoption of certain principles, at least, if nothing further is accomplished. The discussion should be founded on a charitable consideration for the opinions and the acts of others in the profession. Many a man has made initial mistakes unintentionally, and under force of circumstances which he thought excused him, and we particularly need his experience and his later judgment as to the results to the profession in case such practices were adopted generally. If the slate is wiped clean, can we not best formulate a code for the future?

It is particularly the conduct of the petroleum geologist that is before us, and it needs attention because so many have entered the profession in recent years, and because it offers so many temptations to get rich quick, or to build up a lucrative practice. Probably we should view the whole field of those engaged in the work: the college professor, the geologist in government employ, in state employ, the consulting geologist, the geologist in company employ, the man investigating or operating for himself. It would seem entirely proper for this Association with its membership drawn from all of these sources, to adopt principles of general character and also those thought to apply to each of these kinds of employment in petroleum geology.

When the study gets down to kinds of work, it is evident that certain

problems are common to all, while others are limited to a particular kind. Some are simply matters of plain, common honesty, almost beyond dispute, while others involve matters about which opinions may conscientiously differ.

Among the common problems, even though elementary, it would seem to the writer desirable to discuss and adopt conclusions regarding the following:

1. Safeguarding confidential or private information, but making available to others *all* possible, *when* possible.
2. Taking personal advantages, directly or indirectly, of information acquired for another without his consent.
3. Receiving fees or commissions from both parties to a transaction, except with their knowledge.
4. Commending or condemning another geologist except on personal acquaintance with his work.

The other problems, which are more likely to develop differences of opinion, are numerous. Only a few will be mentioned.

1. Splitting fees or commissions for geological reports.
2. Should not one protect himself and profession by requiring that a report may only be published, or submitted for valuation purposes, with his knowledge and consent as to its completeness regarding essential facts?
3. Should one use different valuations on a property when appraising for taxation, sale, purchase, or as a basis of stock sales?
4. May one take **personal advantage** of information gained while in the full-time employ of another, even when gained incidentally?
5. Should one ever charge a high consulting fee for work of an elementary or subordinate **character**, or in an area with which one is not already intimately acquainted?
6. Should a State employee do any private oil work in his state?

These questions have been brought to mind by certain actual occurrences which have seemed to me to be harmful if generally indulged in, but regarding which it may be difficult and perhaps undesirable to formulate rules of conduct. They and others like them might well be referred to a committee on ethics and then reported for a sealed letter ballot by the Association.

F. W. DEWOLF.

AT HOME AND ABROAD

A. H. NOBLE, Chief Geologist of the Corona, is in charge of the Mexican and Mesopotamian geological work for the Dutch Shell.

R. A. CONKLING has been on a pleasure trip in California.

GEORGE MORGAN, of the Empire Gas & Fuel Company, is in Mexico.

J. B. BURNETT, of the Aguila, is in the United States on a vacation.

A. M. MACKENZIE is with the Mammoth Oil Company, mapping Teapot Dome, Wyoming.

WILLIS STORM, of the Sun Company, is in Southern Texas.

P. L. APPLIN, of the Rio Bravo Oil Company is at Laredo, Texas.

W. E. HUBBARD, of Ardmore, expects to move to California in the fall.

W. E. WRATHER will spend the summer in Chicago.

F. B. PLUMMER has resigned from the Dutch Shell interests and is associated with independent operators at Houston, Texas.

THE OKMULGEE Geological Society elected new officers the first Friday in April, for 1922-3; President, Louis Roark; Vice President, Charles A. Warner; Secretary and Treasurer, H. S. Clark.

LEON F. RUSS, 25 Broadway, representing Frankel Brothers, of New York City, was in Shreveport in June, making a study of some of Louisiana's potential oil fields.

GEORGE A. ELLEDGE of Tampico, made a brief trip to Southwest Texas during June.

FERDINAND MORRIS is now in charge of the subsurface work for the Oklahoma Producing & Refining Corporation.

E. H. SELLARDS has prepared a subsurface structure contour map of Bexar County, Texas.

W. T. LEE is studying oil sands in Wyoming.

H. A. LEY is Chief Geologist for the Southwestern Gas Company of Independence, Kansas.

W. W. RUBEY, of the U. S. Geological Survey, is working in Wyoming.

A. C. VEATCH is mapping Teapot Dome, Wyoming, with the assistance of Stanley C. Herold and E. Eggleston Smith.

F. B. TOUGH, of the U. S. Bureau of Mines, has written a brief ex-

planation of the nature of the contract between the Mammoth Oil & Gas Company and the Secretary of the Interior.

The firm of **BATES & LASKY** has been dissolved. Mowry Bates is living at Lindsay, California. B. H. Lasky will continue the work of the partnership, in the Atco Building, at Tulsa, Oklahoma.

J. WHITNEY LEWIS, formerly of the firm of Hager, Bates & Lewis, is now General Manager of the New England Corporation, Ltd., at Maracaibo, Venezuela.

L. G. WELSH, formerly with the Transcontinental Oil Company, has opened an office as Consulting Geologist, in the Atco Building, Tulsa, Oklahoma.

RAYMOND C. MOORE is spending the summer in Utah, for the U. S. Geological Survey.

E. DEGOLYER has been in Europe on a short trip.

A. F. DIXON has been in San Domingo recently.

E. B. STILES on December first accepted a position with the Humphreys Mexia Company, with offices at 1320 Grand Southern Life Building, Dallas, Texas, to organize a sub-surface department similar to that in the Bureau of Economic Geology, at Austin, Texas.

WALTER J. ALLEN is geologist for the Shaffer Oil & Refining Company, at Tulsa, Oklahoma.

LUTHER WHITE has resigned from the Oklahoma Central Oil Company.

FRANK GREEN is now located at 605 Exchange National Bank Building, Tulsa, Oklahoma.

R. D. REED is with the R. B. Whitesides Company, Muskogee, Oklahoma.

KIRK & HOOVER have removed their offices to 432 Mayo Building, Tulsa, Oklahoma.

DAVE M. LOGAN has completed a Dutcher sand discovery well in section 26, T. 13N., R. 13E., near Okmulgee, Oklahoma.

CHESTER NARAMORE recently returned from China.

A. F. MELCHER, of the U. S. Geological Survey, has been studying sand conditions in the Burbank field.

W. P. HAYNES will attend the International Geological Congress Meeting in Belgium this summer.

J. ELMER THOMAS is spending the summer in Tulsa at the office of the Shaffer Oil & Refining Company.

STUART ST. CLAIR has been in China.

R. A. BIRK, of the Amerada Petroleum Corporation, has moved from Duncan to 411 Simpson Bldg., Ardmore, Oklahoma.

W. D. MILLER is geologist for the Planet Oil Company in Texas.

J. P. BOWEN is with the Simms Oil Company in Tulsa.

THE OKMULGEE GEOLOGICAL SOCIETY enjoyed a picnic at Tahlequah, July 1st.

G. E. EBMAYER, formerly with the Mexican Eagle Oil Company, has returned to the United States.

FRANK CARNEY, of the National Refining Company, is located in the Magnolia Building, Dallas, Texas.

PAUL WEAVER, of Tampico, has been in New York City on business.

DAVID DEAN discovered the Gray Bros. structure near Marlin, Texas.

IRVING PERRINE is spending the summer at Ithaca, N. Y.

E. H. BAUMAN is consulting geologist for the Oklahoma Petroleum & Gasoline Company and is living at Graham, Texas.

THE new Breckenridge lime well of the Humble Oil & Refining Co., 15 miles southeast of Albany, in Shackelford County, Texas, was drilled on subsurface structure. The Ibex Oil Company drilled the original well in this area on a small surface structure mapped by Hjalmar Abrahamson.

JOHN SUMAN has spent the month of July in California.

L. P. GARRETT spent part of the summer in the Yellowstone National Park.

ALEXANDER DEUSSEN has been in New York on a business trip.

E. T. DUMBLE has been in California.

R. T. HILL is spending the summer in California.

J. C. ROSS is making a barometric survey of the Okemah District, Oklahoma.

W. A. I. M. VAN DER GRACHT, who has recently been making his headquarters in New York City, is attending the International Geological Congress in Brussels.

W. C. SPOONER has been on a trip to Montana and Wyoming.

W. E. HOPPER has been in Wyoming and Montana.

F. J. MILLER is Division Geologist for The Texas Co. at Shreveport, La.

R. B. KELLEY, of the Bureau of Mines, has been transferred from Bartlesville, to Dallas.

W. R. McLAUGHLIN is in Shreveport.

F. H. BOSTICK is doing subsurface work for the Standard Oil Co. of Louisiana.

H. G. SCHNEIDER, of the Amerada Petroleum Corporation, is working at Shreveport, La.

C. C. CLARKE is representing the Roxana Petroleum Corporation in Mississippi.

L. E. WELLS is with the Arkansas Natural Gas Co. in South Louisiana.

H. D. EASTON, of Shreveport, is working in Mississippi.

RICHARD JONES, of the Humble Oil & Refining Company is in Laredo, Texas.

H. N. SPOFFARD, of the Gladys Belle Oil Co., has returned from El Dorado, Arkansas, to Tulsa.

J. O. NELSON has returned to Shreveport from a business trip to Pittsburgh, Pa.

A. P. WRIGHT, of Tulsa, has been in New York City on business.

K. C. HEALD represented the U. S. Geological Survey at the Osage Sale, June 28th.

WILLIAM D. GRAY has resigned from the Riverland Co. to be an independent oil producer.

A. O. HAYES, formerly of the Geological Survey of Canada and later of the Whitehall Petroleum Corporation, is spending the summer at Coronado, California.

DAVID WHITE has been in Kentucky.

M. Y. WILLIAMS, of the Geological Survey of Canada, is engaged in petroleum work in the Canadian Northwest.

A. RODGER DENISON is office geologist with the Amerada Petroleum Corporation in Tulsa.

J. M. HAROLD is Chief Geologist of the Comar Oil Co.

EDWIN KIRK, of the U. S. National Museum, has recently returned from the Argentine Republic.

R. A. CONKLING is spending his prescribed six months away from the Mid-Continent field.

THE BARTLESVILLE Office of the U. S. Bureau of Mines has prepared a peg model of the Slick oil field, Oklahoma.

O. M. EDWARDS, of the Sun Co., has left Tulsa temporarily.

MARVIN LEE, of Wichita, Kansas, spent part of the summer near Laredo, Texas.

C.W. CLARKE, and DAVE LOGAN have formed a partnership for consulting work at Okmulgee, Okla.

ARTHUR BURRESS is working at Ardmore.

A. C. TROWBRIDGE is examining the delta of the Mississippi River for the U. S. Geological Survey in co-operation with the War Department.

C. E. DECKER has been conducting a field party in the Arbuckle Mountains.

RICHARD HUGHES spent his vacation in Colorado.

THE DIXIE Oil & Gas Co. will drill on the Scotland Seep structure in Telfair County, Georgia, 100 miles southeast of Macon. There is an excellent seepage of both oil and gas from the Alum Bluff formation, of the Oligocene, which is described by J. P. D. Hull and L. P. Teas in a special report of the Geological Survey of Georgia, published in 1919, entitled: "A preliminary report on the oil prospect near Scotland, Telfair County, Georgia."

R. C. SCHROYER, of the Roxana Petroleum Corp., will work in Louisiana.

C. O. DOUB is associated with Foster, Reiter & Sneed at 707 First Nat'l. Bank Bldg., Tulsa, Okla.

H. B. FUQUA is with the Gulf Production Co. at Wichita Falls, Texas.

R. M. BUTTERS is in Laredo, Texas.

M. R. GOLDMAN is working with Frank Reeves at Big Sandy, Mont.

C. R. LONGWELL and W. W. RUBEY are studying the structure of a portion of Wyoming adjacent to the Black Hills.

RUSSELL S. KNAPPEN is mapping structure in the Big Horn basin, Wyoming, for the U. S. Geological Survey.

DAVID WHITE has been designated by the Secretary of State as delegate to represent the Government at the International Geological Congress to be held in Brussels, August 10-19. Mr. and Mrs. White sailed July 29.

A. E. FATH is working for the Standard Oil Company in Poland. He sailed early in June.

M. M. ORR is on a brief trip to Oklahoma and will return to Panama for the Standard Oil Company.

BURTON HARTLEY, of Tulsa, has been in Kentucky on professional work.

W. B. WILSON, of the Gypsy Oil Co., is working in Montana.

JAMES L. TATUM, formerly with the Mexican Eagle Oil Co., is now with the McMan Oil Co., of Tulsa.

Dingwell Petroleum Producing Corp. will make a test with a diamond drill in the northwest corner of section 25, T. 6 S., R. 6 W., Jefferson Co., Okla.

WM L. CLARK of the Phillips Petroleum Co., is working at Bristow, Okla.

R. H. WOOD has been in Washington.

E. G. WOODRUFF, of the Producers & Refiners Corp., has been in Mississippi.

FRANK C. WIEST is with the Freeborn Engineering Co.

DONALD F. MACDONALD has been seriously ill in Rome, Italy.

S. W. WILLISTON, JR., is working in Texas.

D. D. CONDIT, of the Whitehall Petroleum Corp., is in California on a business trip.

J. E. BRANTLEY has returned from Mexico and is consulting geologist for the Atlantic Refining Co., with headquarters in Philadelphia.

MARVIN WELLER has returned from the Punjab, India.

J. O. LEWIS delivered a series of lectures on petroleum at the Massachusetts Institute of Technology.

E. A. TRAGER has been in Tulsa on a vacation.

ELIOT BLACKWELDER is in Ottawa, Kansas, where he is interested in some shallow field properties.

ROBERT E. GARRETT, 905 Petroleum Bldg., Tulsa, is engaged in consulting work.

WM. J. MILLARD of Tulsa, is doing consulting work.

K. P. HANSEN, geologist with the Mexican Eagle Oil Co., at Tampico, Mexico, since March 1920, died of typhoid fever June 26th, in Mexico.

Mr. Hansen was employed by the Minas Dolores, Matehuala, San Luis Potosi, Mexico, before joining El Aguila.

S. J. CAUDILL is spending the summer in the East.

K. D. WHITE is in the Argentine with the Standard Oil Co. of New Jersey.

GEO. E. BURTON and D. K. GREGER, of the Roxana Petroleum Corp., have been examining the Glenn formation, near Ardmore. Mr. Greger and Dr. Erni expect to publish a paper on the Glenn.

L. H. WHITE is spending the summer in Colorado.

J. M. HEROLD was appointed Head Geologist of the Roxana Petroleum Corporation, on July 15th.

PROF. R. D. SALISBURY, who for some weeks seemed to be slowly recovering from a severe heart attack, suffered a relapse about July 10th and since that time he has been very gravely ill.

EUGENE LILLY has returned to his home in St. Paul, Minnesota, after a year and a half in Palestine and Egypt.

W. H. EMMONS is spending the summer in Europe.

WOOD STANLEY is in charge of the geological work in Southwest Texas for the Gulf Production Company.

C. T. LUPTON has returned to Denver, Colorado, after a trip to Northern Mexico and the Laredo district of Texas.

M. L. FULLER has been traveling in England and on the Continent since last March. He recently returned to London from points in Spain and on the Bay of Biscay and does not expect to return to Brockton, Mass., until late in the fall.

HENRY HINDS is in Venezuela.

CARL W. CLARK has his office in the National Supply Building at Okmulgee, Oklahoma.

HENRY CONKLING is with the Roxana Petroleum Corporation at Okmulgee, Oklahoma.

J. F. ROBERTS, 205 S. Cheyenne St., Tulsa, Okla., mounts an up-to-date production map of Ts. 8-16 N., Rs. 8-14 E., inclusive (63 townships) in a book $7\frac{1}{2} \times 4\frac{1}{4} \times 1\frac{1}{4}$ inches in size for \$35.00. The scale of the maps is $1\frac{1}{2}$ inches to the mile.

E. W. SHAW has been in Tulsa.

WM. D. GRAY mapped the structure in sec. 34, T. 23N., R. 8W., Osage County, Okla., where a new Wilcox sand well has been completed.

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NUMBER 5

VOLUME 6

BULLETIN
OF THE
AMERICAN ASSOCIATION
OF
PETROLEUM GEOLOGISTS

RAYMOND C. MOORE,
Editor

SEPTEMBER-OCTOBER, 1922

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VOLUME VI

NUMBER 5

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CONTENTS

Notes on the Pre-Permian Paleozoics of the Wichita Mountain Area	413
By J. V. Howell	

Water Conditions in the Urschel Pool, Marion County, Kansas	426
By E. F. Shea	

Estimation of Reserves of Natural Gas Wells by Relationship of Production to Closed Pressure	444
By Paul Ruedemann and Ionel Gardescu	

Certain Relations Between Production and Structure in Northern Osage County, Oklahoma	464
By Burton Hartley	

GEOLOGICAL NOTES

Oil in Idaho, K. C. HEALD	472
New Producing Depths at El Dorado, Arkansas, V. P. TEAS ..	473
Possible Sub-Sea Anticlines, Gulf of Paria, Trinidad, Venezuela, LEWIS C. CHAPMAN	474
A Chance for More Oil in Southwestern Texas, L. W. STEPHENSON	475
Ordovician Oil at Healdton, SIDNEY POWERS	476

DISCUSSION

Wildcat Wells in South Central Arkansas Stop Short of Deep Oil Sand, J. P. D. HULL	477
El Dorado Oil Field in Arkansas Not on an Anticline J. P. D. HULL	479

REVIEWS AND NEW PUBLICATIONS

Unproved Areas, by Lawrence Vander Leck, W. S. W. KEW	481
---	-----

Bull. Am. Assn. Petrol. Geol.

Appraisal of Oil Production, by J. H. Highsmith

JAS. H. HANCE	483
Oil Finding, by E. H. Cunningham Craig, K. D. WHITE....	485
Manuscript Bibliographies, SIDNEY POWERS	488
New Publications.	

THE ASSOCIATION ROUND TABLE

Committee Work, W. E. WRATHER	489
Membership Applications, W. E. WRATHER	490

AT HOME AND ABROAD

Current News and Personal Items of the Profession.....	493
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Volume VI.

Number 5.

BULLETIN
OF THE
AMERICAN ASSOCIATION
OF
PETROLEUM GEOLOGISTS

SEPTEMBER—OCTOBER, 1922

**NOTES ON THE PRE-PERMIAN PALEOZOICS OF THE
WICHITA MOUNTAIN AREA.**

J. V. HOWELL

INTRODUCTION

During the past three years a large amount of drilling has been done in the area surrounding the Wichita Mountains of Oklahoma, and many samples have been secured from horizons which do not appear at the surface. It is the purpose of this paper to discuss the characteristics of some of these cuttings and to suggest methods by which these and other samples may be correlated.

In the Wichita Mountain area are found outcrops of Pre-Cambrian, Ordovician and Permian rocks only. Beds of ages intermediate between the Ordovician and Permian outcrop in the Arbuckle Mountains and presumably are present in the Wichitas also, but their presence cannot be demonstrated by surface study. Examination of the comparatively large amount of material available from wells in the region has made it possible to prove the presence of some of these beds, but of others there are as yet no traces.

The notes given herewith admittedly are very fragmentary, but they are presented with the hope that some of the suggestions contained may ultimately assist in the solution of the interesting and difficult stratigraphic problems of the Paleozoic beds of southern Oklahoma.

METHOD OF STUDY

In subsurface correlation the following factors are of service:

1. Lithologic character of the beds penetrated.
 - a. Mineralogic and petrologic character.
 - b. Texture. Crystalline or non-crystalline. (Tables 1 & 2). Uniformity. Cracked, fresh, decomposed, etc.
 - c. Color. Wet and dry. In transmitted light.
 - d. Physical character. Hardness, fracture etc.
2. Contents.

Dry. Fresh, salt or mineral water. Oil, gas, etc.
3. Sequence of strata.

Stratigraphic succession. Intervals.
4. Thickness of beds.
5. Fossils.

In this brief paper it is desired to discuss the lithologic character of the pre-Permian rocks, and some of the methods which have been found useful in their study. Factors 2, 3, and 4 can be obtained directly from the log or observation at the well. Study of the lithology can best be made on carefully selected samples, examined in a laboratory, which, however, need not contain elaborate equipment.

As a result of the study of a very large number of samples of shales and sandstones from the Wichita mountain region, the writer has been convinced that little reliable information can be obtained from their microscopic examination. Their lithologic character is too variable to permit correlation except within short distances.

The limestones, however, appear to be more reliable, and it is believed that careful study of a sufficient number of samples will compensate largely for the time thus spent. In such study it is essential to follow a definite plan, apply to each sample the same tests, and so to organize the resulting data that they will best express the relationships of the various beds. Haphazard study is not only discouraging, but may lead to serious errors.

The examination of samples may conveniently be divided into three stages:

A. Superficial examination of cuttings or fragments with a hand lens or low power microscope. This should bring out:

1. Color, luster, fracture.
2. Presence of loose fossils and their identification.
3. Selection of representative pieces for thin sections.
4. Recognition and removal of extraneous material.
5. Presence of sand grains, chert fragments, pyrite, glauconite, etc., which may be included in the limestone.

B. Study of the thin sections.

1. Preparation of the section. If a large number of sections is to be studied a motor driven lathe for grinding will quickly pay for itself in time saved. However, excellent sections can be made by hand.

Select a fragment, preferably somewhat flattened, and polish one side. Cement this flat surface to a slide by means of dry Canada balsam, using a small quantity of the balsam melted over a flame. With a six inch mill file reduce the fragment to a thickness of about 2 mm.—experience alone will show when to stop—then grind carefully on a small carborundum knife-stone until the texture of the slice can be readily seen on examination under the microscope. Complete the grinding on a razor hone, and make the section as thin as possible. All of these operations can best be carried out with dry material, and no water should be used, as it tends to soften the limestone and make it disintegrate. When the slide has been cut to the required thinness (.07 mm. is sufficient), it is mounted in balsam in the usual way. An average limestone chip can be made into a slide by this method in 10 to 15 minutes. With a grinding lathe the time can be reduced one half.

2. Study of the section. While a petrographic microscope is desirable it is by no means essential. Excellent results may be obtained with either the ordinary microscope or with the binocular type. The latter is preferable owing to its convenience for preliminary examination and in searching for fossils.

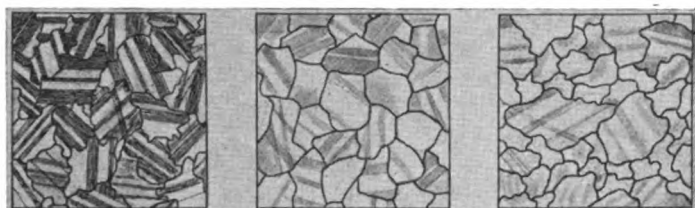
a. Texture. It has been found that, when properly interpreted, the texture of a limestone is one of the best diagnostic characters. However, the wide variations of texture in different limestones is not generally recognized, and is not as readily described and recorded as in igneous rocks.

A German writer, Hirschwald¹ has studied in great detail the textural range of limestones and from his paper the accompanying illustrations have been taken. Hirschwald's original classification includes a great number of subtypes in addition to those shown, but for the present purpose such refinement seems unnecessary. Subclasses, based on type of

cementing material, percentage of coarse and fine grains, and similar characters may be designated if desired, but should be used with care. It is believed that the twenty-four textural divisions shown, together with such special types as oolitic texture, are sufficient for ordinary work. The types may conveniently be referred to by the letters; while any added subtypes can be designated by numerals, as: A2, B3 etc.

The following types have been selected from those of Hirschwald:

1. **Macrocrystalline Limeston. Marble.**
 Numbers A to E more or less interlocking, small to medium grains of calcite or dolomite. Grains .75 mm. and larger. The calcite grains usually show polysynthetic twinning; the dolomite grains do not.
 - A. Calcite grains with polysynthetic twinning and with irregular contact surfaces. Grains uniform in size.
 - B. Similar to A, but with regular boundaries.
 - C. Similar to B, but with grains of unequal size.
 - D. Similar to C but with polysynthetic twinning bands curved, due to dynamic action. Interstitial filling of smaller, broken grains.
 - E. Strongly deformed calcite grains without sharp boundaries. Curved twinning bands. Recemented, kataclastic structure.
2. **Mesocrystalline Limestone.**
 Numbers F to L. Grains .25 to .7 mm. diameter. Calcite grains seldom show polysynthetic twinning. Often have siliceous or argillaceous cement.
 - F. Incompletely intergrown, mesocrystalline grains with microcrystalline cement.
 - G. Incompletely intergrown mesocrystalline grains cryptocrystalline cement.
 - H. Isolated mesocrystalline grains in a microcrystalline ground-mass.
 - I. Isolated mesocrystalline grains in a cryptocrystalline ground-mass.
 - J. Isolated mesocrystalline grains in a pelitomorphic ground-mass.
 - K. Incompletely intergrown mesocrystalline grains with argillaceous or siliceous cement.
 - L. Predominantly mesocrystalline grains with carbonaceous material surrounding the sharp bordered grains.
3. **Microcrystalline Limestone.**
 Numbers M to Q. Grains .01 to .1 mm. in diameter. Crystalline texture recognizable only under the microscope.
 - M.N. Uniform texture, crystal boundaries sharp, wholly microcrystalline. N shows refilled fracture.



A

B

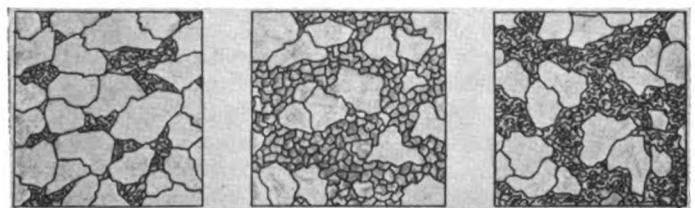
C



D

E

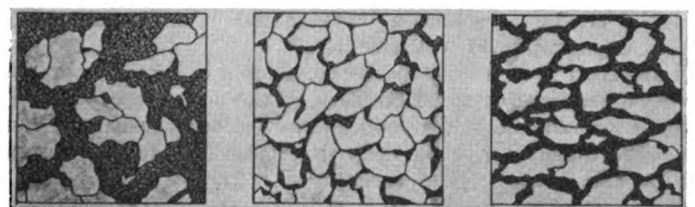
F



G

H

I



J

K

L

Plate I

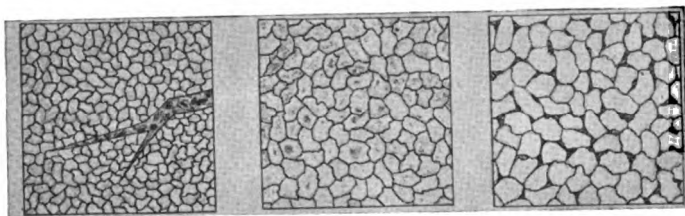
Textural types of limestones, as seen in this section. After Hirschwald.

- O. Incompletely intergrown microcrystalline grains with siliceous or argillaceous cement.
- P. Chiefly microcrystalline but with some areas of cryptocrystalline material.
- Q. Chiefly microcrystalline but with proportion of cryptocrystalline larger than in P.
- 4. Cryptocrystalline and Pelitomorphic Limestone.
 - Numbers R, S, T. Under very high magnification (400x-600x) the texture is shown to be crystalline.
 - Pelitomorphic limestone consists of an aggregate of the finest calcite grains (.003-.005 mm. diameter) whose boundaries cannot be recognized except in polarized light. Under the ordinary microscope it appears as a fine granular aggregate.
 - R. Prevailing cryptocrystalline, subordinately microcrystalline.
 - S. Prevailingly cryptocrystalline, subordinately pelitomorphic.
 - T. Prevailingly pelitomorphic, subordinately cryptocrystalline.
- 5. Shaly Limestone.
 - U. Limestone with thin parallel shaly lamellae.
 - V. Limestone veined with streaks of shale flecked through it, inside of which the limestone is completely isolated to form lenses and nodules.
- 6. Siliceous limestones.
 - W. Limestone uniformly permeated with silica. Sometimes shows distinct parallel structure.
 - X. Limestone permeated by quartz, which has separated out in the form of bunches, streaks and irregular masses.
- 7. Oolites. Chalk.
- 8. Limestone composed chiefly of organic debris, fragments of fossils, shells etc., which are not recognizable. If coarse would be called coquina.
- C. Determination of Amount of Dolomite in Limestone.

Determination of the amount of dolomite in a limestone by the usual chemical methods involves many hours time, the use of elaborate equipment, and the possession of considerable skill. The average geologist is therefore unable to make use of this character in the routine examination of well samples.

In an effort to find some means by which a rapid and approximately correct determination could be made of the dolomite content of limestone, use was made of two well known processes, which, in combination, were found to give the desired result. The method may be outlined as follows:

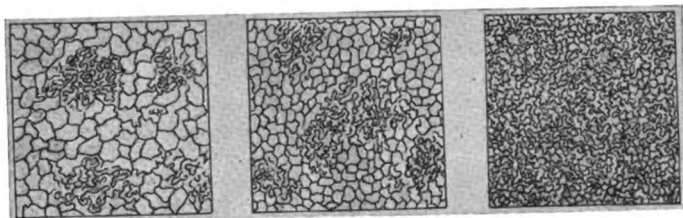
 - 1. Crushing of the sample to a fine powder.
 - 2. Screening with sieves to obtain a product in which all the particles are of uniform size.
 - 3. Staining of the sized product in such manner that the grains of calcite and dolomite can be readily recognized.



M

N

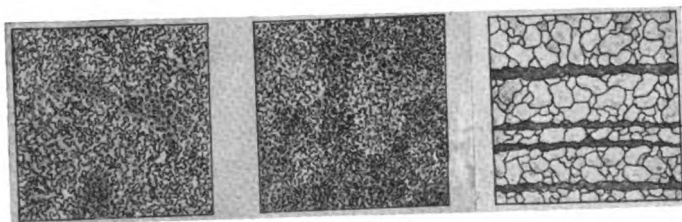
O



P

Q

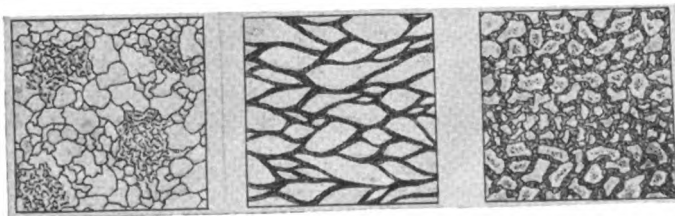
R



S

T

U



V

W

X

Plate II

4. Counting of the stained grains. The relative numbers of calcite and dolomite grains will closely approximate the percentage of the two minerals in the rock.

Crushing. This may be done in any convenient mortar, but owing to the small amount of material ordinarily used, a 2-inch agate will be found most convenient. The sample should be ground until all will pass the $\frac{1}{4}$ mm. screen.

Screening. Two screens are necessary, of $\frac{1}{4}$ mm. and $\frac{1}{2}$ mm. mesh respectively. The sieves ordinarily procurable are much larger than necessary, and a more convenient size can be made from a 2-inch tin such as is used by druggists to contain ointment. The bottoms of two such tins are cut out and replaced by small pieces of screen of the desired fineness, which can be purchased from most dealers in apparatus.

All of the sample that passes the $\frac{1}{4}$ mm. screen and remains on the $\frac{1}{2}$ mm. is placed in a watch glass. The finer material which pass $\frac{1}{2}$ mm. is placed in a second glass. There are thus obtained two portions, one of which includes material ranging in size between $\frac{1}{2}$ mm. and $\frac{1}{4}$ mm. and the other being less than $\frac{1}{2}$ mm.

Staining. A number of methods have been recommended for differential staining of calcite and dolomite, but the one which is simplest and most effective is that of Lemberg.

To a small quantity of the sized material on a watch glass there is added a few drops of $N\div 10$ $AgNO_3$. The powdered mineral is left in the reagent for two to five minutes and then carefully washed with distilled water from a fine tipped wash bottle. A drop of $N\div 10$ $K_2Cr_2O_7$ is then added and after a few seconds removed by washing.

The powder is then dried, and examined under a hand lens or microscope. Grains of dolomite will be found to remain unstained, while the calcite becomes a deep red, due to the formation on its surface of a film of silver chromate. The intensity of the stain depends on the length of time during which the silver nitrate is allowed to act. Two minutes is long enough under ordinary circumstances. Thorough washing is essential in order to remove all silver nitrate which fails to react with the calcite.

Counting. A count may be made by sprinkling the stained material on a ruled grating, of a size which will depend on the magnification used. Such a grid may be ruled off on white paper and photographed down to the required size, the negative then being used as a counting plate. A black ground is best.

The number of dolomite and calcite grains in five to ten squares is noted, and the proportion of each computed. This proportion is taken as the percentage of each in the original rock.

The counting method given above has been found accurate enough for ordinary work, but if greater refinement is desired, the reader

is referred to Technical Paper 221 of the U. S. Bureau of Mines, where several more exact methods are described. It is best to determine separately the material that passes the $\frac{1}{16}$ mm. screen in order to be sure that an exceptionally large amount of either omite or calcite is not contained in either one.

Formation	Thickness	Mineral Character	Texture	Physical Characters
Arbuckle	4,000 to 6,000	Calcite with five to ten per cent dolomite. Argillaceous in places. Stains well.	<i>B—D</i> <i>M, N</i>	Coarse to medium texture, holocrystalline. Cuttings buff—gray—white. Practically marble. Sections show more or less organic matter, chiefly segregated into rounded or concretionary masses.
Simpson				Some impure limestone with much dark green and gray shale and occasional sandstones,
Viola	500 to 750	Calcite. No dolomite.	<i>R—S</i>	Gray color; sharp conchoidal fracture. Dense.
Upper Hunton	Has not been recognized			
Lower	Has not been recognized			
Pennsylvanian	8,000 to 16,000	Calcite only. No Idolomite. Some beds show much clayey material.	<i>Q—T</i> <i>Groundmass</i> <i>H to J</i> <i>on fossiliferous sections.</i>	Texture generally fine, and crystallization indistinct. Much organic material, both in the form of fossils and broken debris, is present in most sections.

DESCRIPTION OF FORMATIONS

Arbuckle Limestone. In the vicinity of the Wichita mountains the petroliferous sands of the Simpson, the lowest known oil bearing horizon, are immediately above the Arbuckle limestone, and in a large part of the area the Pennsylvanian lies upon the beveled edges of the Ordovician beds. Hence the Arbuckle may be considered the "farewell rock,"

below the top of which it is useless to drill, and its ready recognition become a matter of great importance.

The Arbuckle formation has a maximum thickness of about 6,000 feet, all of which is limestone, with only very slight partings of shale. The lateral and vertical variations in lithologic character are relatively slight, and the formation as a whole is remarkably uniform.

Examination of a number of slides from both wells and outcrops has brought out the following fairly constant characteristics:

The texture generally is coarse, mesocrystalline to macrocrystalline. the range is from *B* to *D* and *M* to *N*, although texture as fine as the latter is exceptional. Occasional clearly definite calcite rhombs occur. The extinction angles of the various crystals are irregular, and samples from near the Wichitas sometimes show many more or less rounded masses of what appears to be organic matter. The fact that this has been gathered into masses may possibly be interpreted as a result of metamorphism. In some samples the material approaches a true marble, but this is by no means the rule. Fossils are extremely rare in sections, although somewhat more common in outcrops.

Megascopically the Arbuckle often is white to buff in color and the cuttings have a granular or "sugary" appearance, much like that of discolored marble.

A characteristic feature of the Arbuckle is the constant presence in all samples examined, of a small amount of dolomite ranging from two to ten per cent. This is readily detected by the methods described above, and is of great assistance in distinguishing the Arbuckle from the Viola, with which it is often confused. The Viola contains no dolomite.

Simpson formation. Although the Simpson has not been definitely recognized in the Wichita area, its presence has been inferred. Oil in the Granite, Gotebo, and Gladys Belle pools is distinctly different from known Pennsylvanian oils found nearby, and the locations of these pools are such that it seems probable the oil has originated in the Simpson. It does not outcrop about the Wichitas, so far as known, and as

no authentic samples are available, no data concerning its microscopic character are given.

In the Arbuckle mountain region the Simpson is composed of dark green or blue shales, rather impure thin-bedded limestones and occasional sandstones. There are many fossiliferous horizons, but the microscopic fauna has not been carefully studied.

Viola limestone. Immediately above the Simpson formation lies the Viola, a thick bed of limestone 500 to 750 feet thick. It is especially important that this formation be not confused with the Arbuckle, since if the Viola be reached at a reasonable depth, drilling through it to the productive horizons may be recommended.

The Viola outcrops near the Wichitas is a few small areas only, at Rainy Mountain Mission, near Gotebo. It has been found in a shallow well on the west edge of Lawton, and in several wells farther from the mountains. In all cases the lithologic characters are very similar.

Fragments of the Viola appears dense, light to dark gray in color, break with a sharp sub-conchoidal fracture, and bear a close resemblance to lithographic limestone. In thin sections the texture commonly is rather uniform, *R-S*. In a few slides a phase resembling *I* has been found, but this seems to be exceptional. No fossils have been found. There are occasional irregular and indefinite rhombs of calcite, usually small.

In no sample tested was there to be found a measurable amount of dolomite, and this lack of magnesium carbonate is believed to be constant.

Hunton formation. No beds corresponding to the Hunton have been identified in the Wichita mountain region.

Pennsylvanian limestones. The limestones, shales and sandstones of the Pennsylvanian have certain distinguishing characteristics by which one acquainted with them can usually recognize them, but to describe these features is far from easy. As would be expected, limestones afford the best means of correlation.

The limestones fall naturally into two classes; those which are composed chiefly of fossils or organic debris, and those

in which fossils are rare or absent. The textures of the two classes are markedly different. In the highly fossiliferous varieties, especially in samples from wells in the extreme southwest part of the area, the texture of the groundmass is *H-J*, while in the unfossiliferous varieties it approaches *Q-T*.

The Pennsylvanian limestones are non-dolomitic, and composed chiefly of calcite, with more or less argillaceous material. The texture generally is microcrystalline or pelitomorphous although some slides show small areas of rather coarsely crystalline calcite. The texture commonly varies in different parts of the same slide, and veinlets and irregularly shaped areas of secondary calcite are frequently seen.

The hardness varies also, but for the most part the limestones are somewhat softer and more readily ground down than are those of the older formations. The color depends chiefly on the impurities present, especially the amount of shale. Greenish and brown tints are common. Radiating masses of aragonite have been seen in a few samples from the north Duncan field.

There are no noticeable evidences of metamorphism. The organic fragments usually are well preserved, and no tendency has been noted for the segregation of such masses of organic material as were noted in the Arbuckle limestone. The non-fossiliferous limes commonly appear granular, rather than distinctly crystalline when examined under low or medium magnification.

The fossils usually found are those of small size, which are not readily broken up by the drill. These have been little studied, many of them are undescribed, and their ranges unknown. The only way in which they can be made of much assistance in correlation is by direct comparison. Ostracoda, foraminifera, echinoid plates and spine fragments, sponge spicules, and small bryozoa are found in great abundance in certain horizons. The thick limestone found in the wells of the Lone Star Gas Co., Sec. 35, T. 6 N., R. 26 W., at 2600-3000; Elmhurst Development Co., Sec. 3, T. 1 N., R. 24 W., from 2650-3100; and Auto Oil Co., Sec., 25, T. 4 N., R. 26 W., was composed very largely of organic fragments, with many

well preserved ostracods, bryozoa, and a few foraminifera. The fossils from the Elmhurst well were submitted to Mr. P. V. Roundy, who considered them to be Pennsylvanian, although he was unable to place them more closely.

WATER CONDITIONS IN THE URSCHER POOL
MARION COUNTY, KANSAS¹

By E. F. SHEA

Introduction.

Location and history of development

Structure

Surface

Subsurface

Producing Horizons

Description

Analyses

Production

Methods

Character and treatment of oil

Water Encroachment

Occurrence of water

Early evidence of encroachment

Method of studying encroachment

Methods of handling wells

Effects of water on equipment—Analyses

Effect of water encroachment on well decline

Conclusion

INTRODUCTION

The data contributed in this paper were obtained while making a study of water conditions for the Amerada Petroleum Corporation on their D. F. Urschel lease in the northwest quarter of section 21, Township 21 South, Range 5 East in the Urschel pool. Some of the facts brought to light seemed to be of general interest and at the suggestion of Dr. Sidney Powers, Chief Geologist, these facts as interpreted are here presented.

The surface structure contour map accompanying this paper was made by C. R. Thomas prior to the drilling of the discovery well. Thanks are due to Dr. Powers, Miss Dollie Radler, and others in the Geological Department of the Amerada Petroleum Corporation for their assistance and helpful suggestions in the preparation of charts and manuscript.

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LOCATION AND HISTORY OF DEVELOPMENT

The Urschel, or Florence-Urschel pool as it is more commonly called, is the farthest north and east of that group of oil fields, lying immediately to the west of the "Granite Ridge" in central Kansas. The pool is located about 3 miles south and east of the town of Florence in Marion County and occupies parts of sections 16, 17, 18, 19, 20, 21, 28 and 29, T. 21 S., R. 5 E.

The first well within the present limits of the pool was drilled early in 1920 by the Robinson Petroleum Company, on the J. T. Greeley farm in the southwest corner of the southeast quarter of section 18. Pay sand was encountered at a depth of 2,396 feet and the well started off with an initial production of about 150 barrels of oil and considerable water. This well was located on a small surface nose lying to the west of the major structure. Subsequent investigation disclosed the presence of the larger structure in sections 16 and 21 and resulted in the drilling of a well in the southeast corner of the west half of the southwest quarter of section 16 which is commonly considered the discovery well of the pool. This well was drilled by Merriam & Findeiss and the National Refining Company on the D. F. Urschel lease and was completed July 21st, 1920, in sand at 2,306 to 2,318 feet with an initial daily production of 2,928 barrels.

From this discovery, development rapidly extended into the adjoining section. By the close of the year 1921 the pool, with the exception of the extension southward into section 28, had been fairly well defined by dry holes. It has at present a proved area of about 1,500 acres.

STRUCTURE

Surface. The surface structure was determined by plane-table elevations on the beds of the Winfield, Doyle and Ft. Riley limestones and the Florence flint which cap the low rounded hills lying between the tributaries of Cottonwood River, and Doyle and Cedar Creeks. It consists of an anticline with a long curved axis which lies immediately west of the "Granite Ridge arch" and extends from the northeast corner of section 16 through the center of section 21 and into

one occupying the north half of section 18 and the other, the northeast quarter of section 30.

Subsurface. The subsurface structure, as defined by datum elevations on the producing horizon, shows very little conformation with the surface (Fig. 2). It consists of an anticline with the long curved major axis extending in a north-south direction from the center of the northwest quarter of section 28 into the northwest quarter of section 21. Swinging westward the axis extends along the south line of section 17 for about a quarter of a mile where it divides, one branch trending southward through the center of section 20 while the other continues westward to the east side of section 18. From this point the dip to the west is abnormally steep amounting to about 75 feet in a half mile. Along the major axis there are a number of irregular "closures." From the center of section 21 to the center of section 22 there is a maximum east dip of about 70 feet on the producing sand. Several minor synclines interrupt the regularity of the major structure and give rise to the local closures. Of these synclines the one in the east half of section 20 is the largest and has the greatest influence on the shape of the structure.

PRODUCING HORIZON

Description. The producing horizon of the Urschel pool which is encountered at a depth of about 2,300 feet is generally considered to be the stratigraphic equivalent of the pay sand in the Covert-Sellars and Elbing-Peabody pools. It is placed in the Tyner formation of the Ordovician¹.

From a study of the character of the "sand," the nature of the production and the results of deepened wells, the writer is led to believe that the Urschel sand may represent an old erosional surface of the Ordovician siliceous limestone.

The thickness of the actual oil bearing "sand" ranges from a few inches to a possible maximum of 12 feet in one well. The average thickness however, probably does not exceed 2 or 3 feet.

The pay "sand" is nowhere a true sand, but is composed

¹ F. L. Aurin, G. C. Clark and E. A. Trager, Notes on the Subsurface pre-Pennsylvanian Stratigraphy of the Northern Mid-Continent Oil Fields, Amer. Assoc. Petroleum Geologists Bull. vol. 5, No. 2, 1921, pp. 47-153.

directly overlies the granite. No measurement of the porosity of the sand was obtained but the evidence all points toward an unusually large amount of pore space.

Analyses. A rather simple quantitative analysis was made of a number of well cuttings. Each sample was carefully weighed, digested in a dilute solution of hydrochloric acid, evaporated to dryness and reweighed, and the residue examined under a microscope. The soluble portion was considered to be calcium carbonate. The crystalline quartz and cherty material were separated under the microscope. The results of some of these analyses are given in the following table:

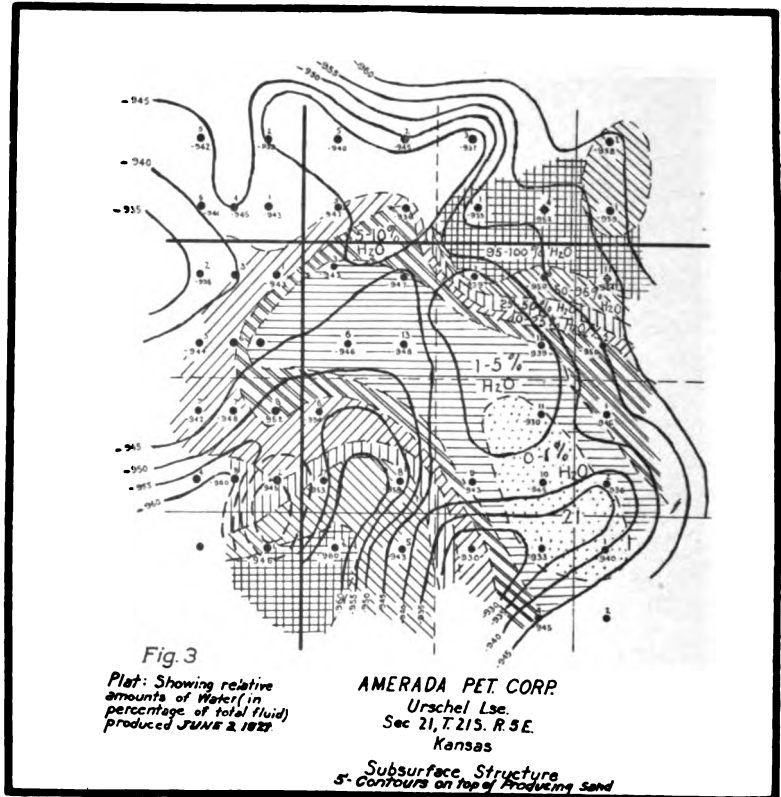
Sample No.	Lime	Chert	Crystalline Quartz
1	13 percent	87 percent	trace
2	51 "	42 "	7 percent
3	8 "	65 "	27 "
4	15 "	84 "	1 "
5	36 "	64 "	trace
Average	24.6 "	68.4 "	7 percent

PRODUCTION

Methods. No gas whatever was encountered in the Urschel pool. The wells owe their pressure entirely to water and very few of them flowed naturally except for short periods under agitation. The only notable exception to this rule was No. 5 well on the Amerada lease which flowed naturally for about six weeks at a rate of over 1,000 barrels daily of pipe line oil. It was then put on the swab for awhile, and later, on the pump but the production declined rapidly. Most of the wells filled up with oil as soon as the sand was penetrated and were either swabbed for a time or were at once tubed and put to pumping. Swabbing was a common practice with the earlier wells of the field and some very large daily yields were obtained. Such extreme "pull" on the wells, however, fostered a more rapid increase in water and later wells were tubed and pumped as soon as completed.

The initial daily production of wells showed a rather wide range, from 2,800 barrels in the discovery well to as low as 10 barrels or less in some of the edge wells. Even in offset wells the variation was sometimes marked. On the Amerada

Petroleum Corporation lease well No. 13, just a location away from No. 5, the large flowing well had an initial production of only 60 barrels daily. It was completed several month after No.

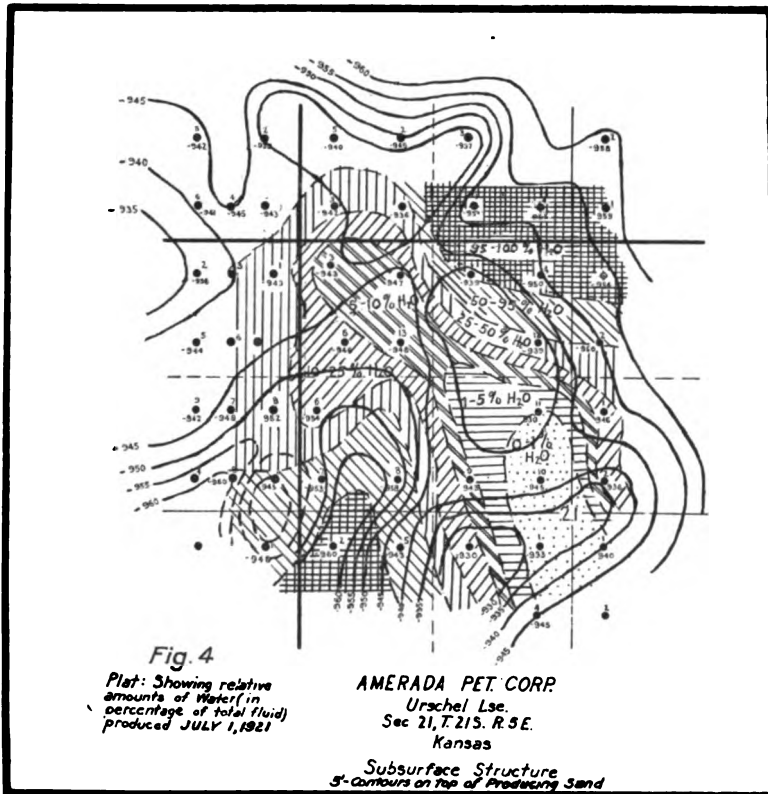


5 and its small capacity was probably due to drainage, which would no doubt be very active in a thin porous sand.

The average initial daily production throughout the field was probably 250 to 300 barrels. Ten acres per well is about the usual spacing. With few exceptions the wells are operated on the unit system. Each well is equipped with an oil engine and pumped on the beam.

Character and treatment of oil. The oil from the Urschel pool is black in color and tests from 33° to 34° Baume. Due to the presence of a large amount of water and B. S., treat-

ment is necessary before the oil can be run into the pipe lines. Steaming and treating with lime is the common practice.



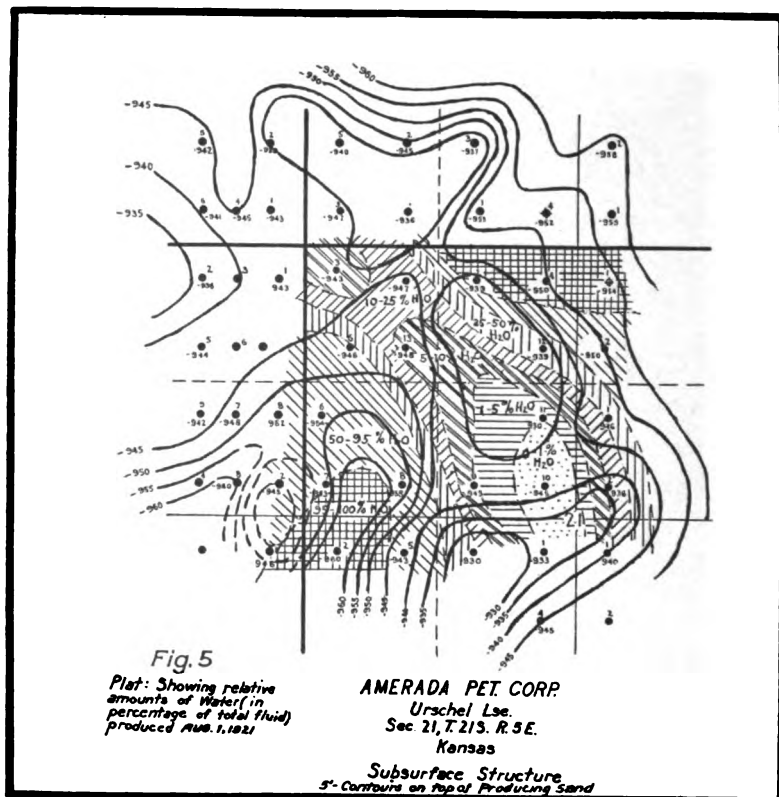
Each lease has its own treating plant capable of handling several thousand barrels of fluid daily.

The Prairie Pipe Line Company and the Sinclair Pipe Line Company each has a line into the field and transport most of the oil.

WATER ENCROACHMENT

Occurrence of Water. The biggest factor to be considered by operators in the Urschel pool and the one with which this paper primarily deals is the problem of water encroachment. It is entirely a problem of edge water, i.e., water within the

pay sand itself, either immediately below the oil on the crest, or entirely filling the sand along the edges of the structure. As proved by experience any well in the pool if drilled below the oil pay would find water in the base of the sand. There

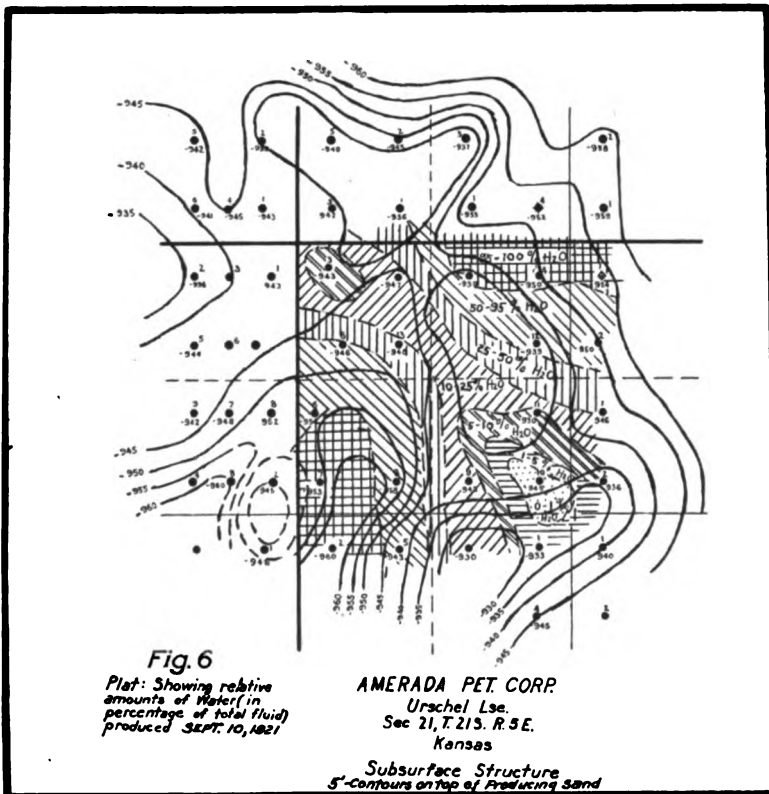


is no apparent break or parting between this water and the oil pay. The separation seems to be merely a matter of gravity and sand porosity.

Early evidence of encroachment. The discovery well penetrated the sand 12 feet and many of the earlier wells drilled near the discovery well penetrated 4 to 8 feet without showing water. However, within a very few weeks, often within a few days, water appeared in these wells and operators soon learned the folly of drilling beyond a foot or two into the sand.

With deeper drilling no increase in oil could be noticed, but the chert became lighter in color and water soon appeared. On the Amerada lease none of the later wells penetrated the sand beyond 18 inches.

In order to determine the elevation of the water with



reference to the structure on the sand, data were obtained which showed the water to exist at higher levels on the east side of the structure than on the west. On the Amerada Petroleum Corporation lease water was encountered in well No. 2 at an elevation of -941, while in No. 1 no water was showing at a total depth of -953. The same condition seemed to exist throughout the structure. This is rather clearly shown on the map (Fig. 2). Production on the east side of

the structure cuts off very sharply above the -960 foot contour while on the west and southwest it extends down in many places to the -980 foot contour. It is noticeable that no production was obtained east of the axis of the surface structures.

Method of studying encroachments. In making a study of conditions on the Amerada Petroleum Corporation lease it was early predicted that there would be more or less marked encroachment of the water upon the lease from the northeast and the southwest through the two pronounced synclines. In order best to demonstrate this, a progressive series of charts showing the conditions at thirty day intervals from June 1 to Dec. 10, 1922 (Figs. 3-9) were prepared. The method adopted in constructing these charts was to plot for each well the ratio of water to total fluid produced, as expressed in percentages, and to contour these percentages. The area of equal percentages were emphasized by cross-hatching. This method assumes a regularity not strictly true, because the contours probably should in reality swing in slightly toward each well and bulge outward in the areas between. However, the difference would not be great as is shown by the result of completing an inside location on the lease.

Well No. 14 completed some time after the last chart was constructed (Fig. 9) in the center of the southeast forty acres of the lease started off making 40 percent water, which is about the ratio predicted from its location on the chart.

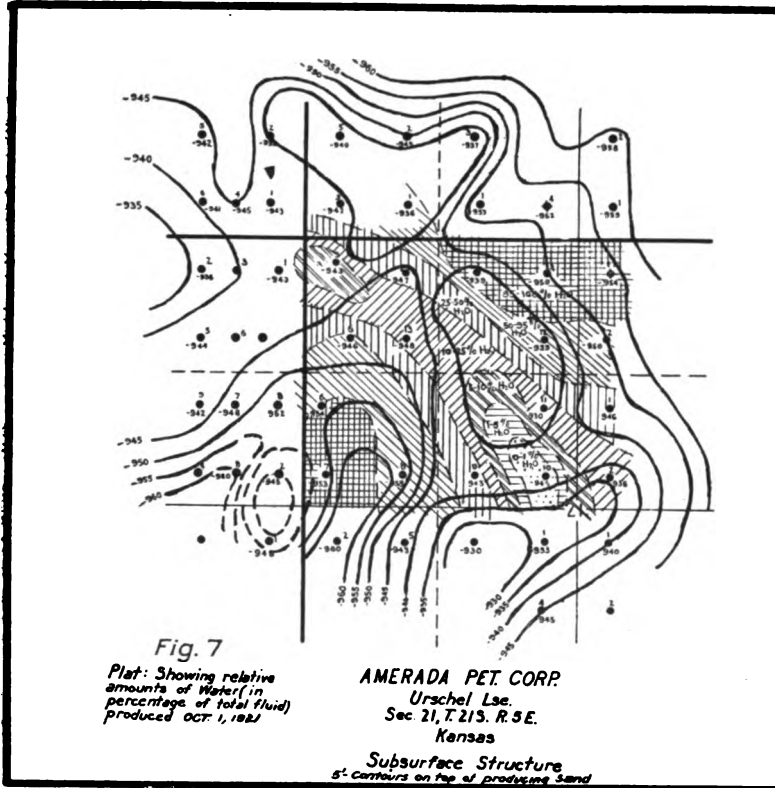
Two additional factors which might also give a wide variation in results are the sand penetration and the method of handling production, both of which have a direct bearing on the amount of water produced.

The charts were prepared from data obtained on the lease. "Bleeders" were installed at each well and samples of the fluid collected from time to time. The samples were run through a small centrifugal hand separator to separate and measure the percentage of oil, B. S. and water.

With greatly increased percentages of water the samples obtained at the wells are somewhat less accurate in the ratio of water and oil, varying with the condition of the well. For this reason the charts were made allowing a wider range for percentages as the water increased. Except in cases of abnor-

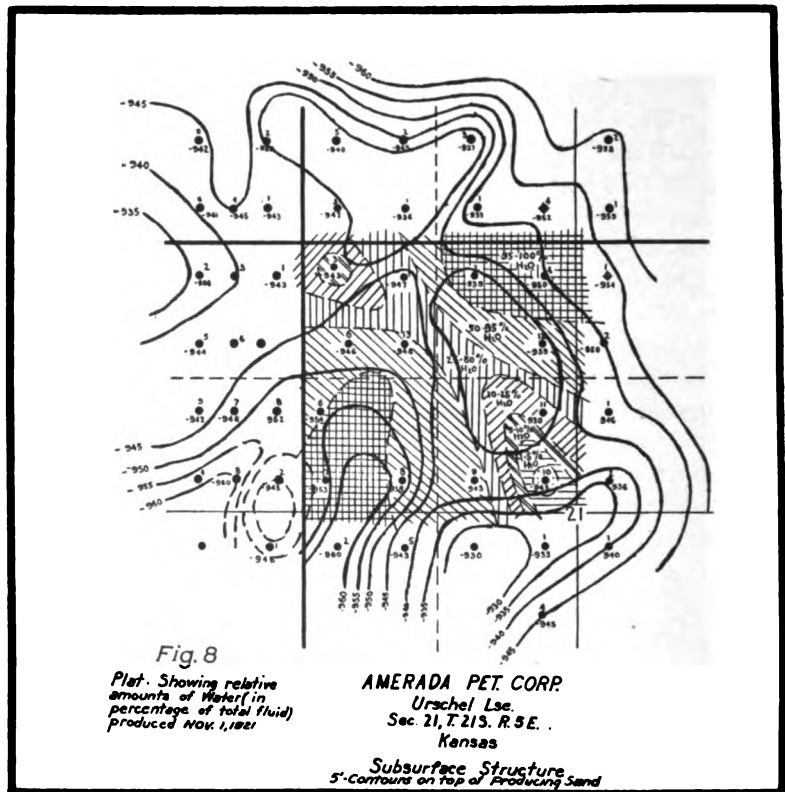
mal amounts the B. S. was included with the water in figuring the percentages.

A study of the charts shows clearly a progressive increase



each month in the amount of water. The areas of small water percentage gradually contract and withdraw around the most persistent wells (Nos. 3 and 10), while the areas of higher water percentage expand and encroach. A comparison of conditions June 1st with those of Dec. 10th (Figs. 3 and 9) summarizes the progress of seven months and shows a very marked increase in the amount of water being produced. Well No. 10, the last to be affected, had commenced to show water. Well No. 2 had been abandoned, while others had increased from a few percent to over 80 percent water.

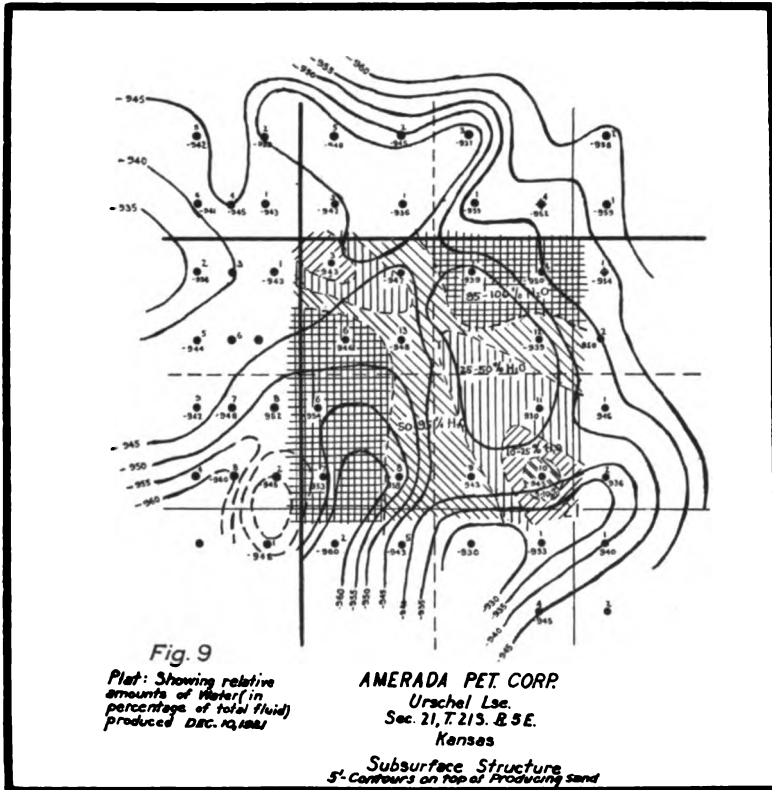
Data on the wells offsetting the Amerada lease were not always available. Few of the other companies kept any record of the water conditions and the wells were not equipped to collect individual samples. Such general data as were obtained, however, showed the same conditions of encroachment to exist throughout the field. A recent check of some of the



offset wells shows water percentages very close to those anticipated. The writer made a recent survey of the field (May, 1922) and from data obtained has estimated that between three and four barrels of water are being lifted for every barrel of oil produced.

Methods of handling wells. Very few of the wells within the limits of the pool have been abandoned although many of

them produce little except water. In this way excessive pressure is kept off of the good wells so that they may recover more oil. Practically all wells are pumped "straight time"



(24 hours a day). Many different methods are being employed to increase production and to reduce the amount of cut oil. Most of the wells are pumped through 3-inch tubing. On some wells, however, 5 inch casing is being used as tubing and the amount of fluid produced greatly increased. Other wells which have a tendency to "pump off" are equipped with 2-inch tubing in order to reduce the production of fluid and enable the wells to be pumped straight time. Adjustments in the length of stroke, the rate of pumping, and the position

of the working barrel are made to suit the condition of the individual well.

Those wells making a high percent of water usually show very little B. S. while the best wells show the effect of encroachment more in an increase in B. S. than in free water. The amount of B. S. is variable and subject to pumping conditions.

The data obtained on the lease of the Amerada Petroleum Corporation were especially useful in the handling of individual wells and in determining the number and location of inside wells.

Effects of water on equipment—Analyses. The water in the Urschel pool is extremely salty and has a noticeable sulphur odor. It has a marked acid reaction as it pits the rods and eats holes in the tubing and line pipe in a very short time. The corrosive effect varies greatly, being much more intense in some wells than in others.

The following analyses of water samples taken from two wells on the Amerada lease were made by Mr. Robert M. Isham:

Constituent	Well No. 8 Parts per Million	Well No. 12 Parts per Million
Hydrogen Sulphide	89.76	6.46
Silicic acid	17.0	16.0
Sodium chloride	11,789.0	12 211.0
Magnesium chloride	753.0	758.0
Calcium chloride	462.0	200.0
Calcium sulphate	405.0	1,032.0
Calcium carbonate	577.0	453.0

In the opinion of Mr. Isham, "the corrosive action of this water is undoubtedly due entirely to the hydrogen sulphide, as the presence of the calcium carbonate, in solution as bicarbonate, precludes the possibility of any free hydrochloric or sulphuric acid." This opinion is substantiated by the fact that water from well No. 8, which has the higher hydrogen sulphide content, shows a much stronger corrosive effect.

EFFECT OF WATER ENCROACHMENT ON WELL DECLINE

The most notable effect of the encroachment of edge water in the Urschel pool is upon the decline in production of indivi-

dual wells. On the Amerada lease alone the wells show a variation in monthly production, decline, ranging from wells with no decline to those abandoned within the first twelve

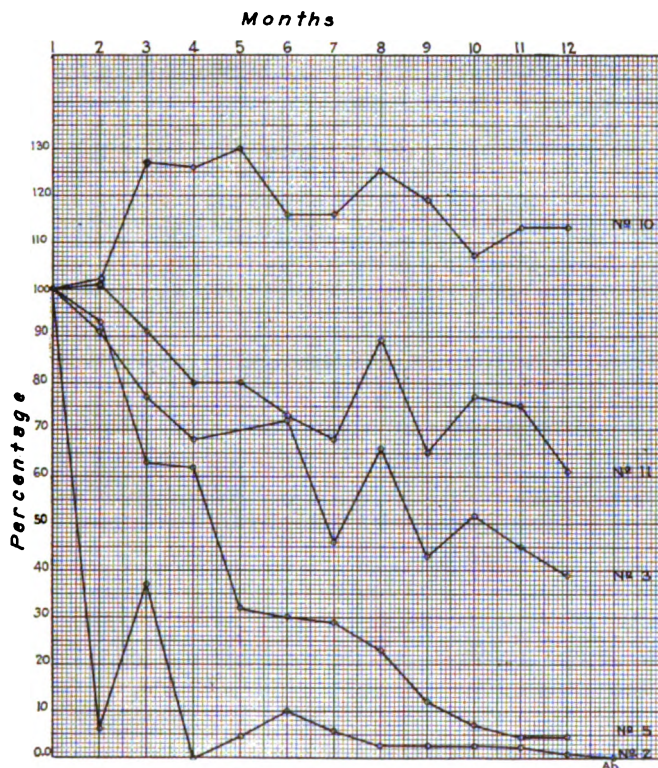


Fig. 10. Chart showing the decline in production by months for several wells on the Amerada Petroleum Corporation lease in the northwest quarter of section 21, T. 21 S., R. 5 E., Florence-Urschel pool.

months (Fig. 10). There is apparently no type decline curve for the pool. A fair average curve might be drawn for a group of wells but the chance of any particular well in the group following that curve is remote.

The decline curves shown on the accompanying chart (Fig. 10) are based on actual production figures for several wells on the Amerada lease. A comparison of these curves with the location of the wells on the charts showing water encroachments (Figs. 3-9) brings out clearly the close connection be-

tween the two factors. The wells which have best resisted water encroachment show a very gradual decline in production and a consequent abnormally high recovery of oil. The edge wells on the other hand show an extremely rapid decline and a low recovery of oil.

The same variation in the decline of wells is known to exist on other leases within the pool.

CONCLUSION

The Urschel pool with a proved area of about 1,500 acres had produced to Aug. 1, 1922, approximately 10,300,000 barrels of oil, an average per acre production of 6,866 barrels. The discovery well in the pool at that time was only 24 months old. The average age of the pool was considerably less than two years. The highest average daily production was obtained during March 1921 when the pool produced an average of 30,230 barrels per day from 85 wells. There has been little change in the number of producing wells since Aug. 31, 1921 when there were 145 wells producing daily 23,000 barrels of oil. Completion since then have just about offset the abandoned wells and the pool in July, 1922, had an average daily production of 7,890 barrels from 150 wells. The early encroachment of water in an oil pool is very commonly looked upon with the greatest pessimism and foreboding and quite often the consequences justify this attitude. When water first appeared in the Urschel pool it was frequently predicted by many interested persons that the pool would never pay out. For some edge leases this may be true, but for the pool as a whole there is no reason to believe that it has not made a very good return on the money invested.

It thus appears to the writer that the encroaching water where properly handled, has aided rather than retarded production. That it has given a more rapid and better recovery than many pools under gas pressure seems apparent from a number of facts. The higher wells show such abnormal persistence—much higher than the average gas pressure well—that we are forced to believe they are recovering much of the oil carried past the lower wells. A recovery of 8,000-10,000 barrels per acre from a sand not to exceed 3 feet in thickness

is quite remarkable. We must either admit the recovery of a very high percentage of the entrapped oil or else assume a porosity entirely out of reason. Some of the higher wells have already recovered from their drainage areas almost as much oil as could be held in the three feet of sand if it were one hundred per cent porous.

Figures for the first half of 1922 show the production to be fairly well settled and at the present rate of decline a total ultimate recovery of approximately 9,000 barrels per acre, or 13,500,000 for the pool, may be expected. The ultimate recovery from the best 10 acres in the field will be at least 30,000 barrels per acre.

ESTIMATION OF RESERVES OF NATURAL GAS WELLS BY RELATIONSHIP OF PRODUCTION TO CLOSED PRESSURE

By PAUL RUEDEMANN¹ and IONEL GARDESCU²

Within the last few years the necessity has developed for estimating recoverable reserves on oil and gas properties. In connection with valuations for Federal taxation, it has been stipulated that appraisals must show fair market values based primarily upon representative transactions in the vicinity. This it has been more readily possible to do with oil than gas. In the case of the latter, the transactions are perhaps ninety-nine times out of a hundred limited to sellers, without a competitive market and in consequence, the requisite factor of a willing seller and willing buyer do not exist.

The natural gas industry was, therefore, obligated to obtain a fair valuation by other methods, and left the task to the engineer. Thus, in the short period of about three years the Annual Analytical method of appraisal has been developed to apply to gas properties. The method consists chiefly in estimating by years quantities of gas to be recovered in multiplying by predicted future price and in discounting,—allowance being made for cost of operating, and the cost of future development on wells not yet drilled.

It is of major importance that the estimation of reserves and the rate of recovery be carried out as accurately as possible, as this has more weight on the final result than any other factor in the appraisal, and is likewise the most difficult to ascertain.

An engineer in appraising oil properties has only one type of data available, production of the wells. This is given at least by monthly records. On gas wells, however, production data at the wells are not available except in rare instances,

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²Asst. Appraisal Engineer, Johnson, Huntley & Somers. Pittsburgh, Pa.

and for Federal taxation purposes, appraisal must be according to the value at the well. Not only this, but since production is not metered, tests for estimation are made instead,

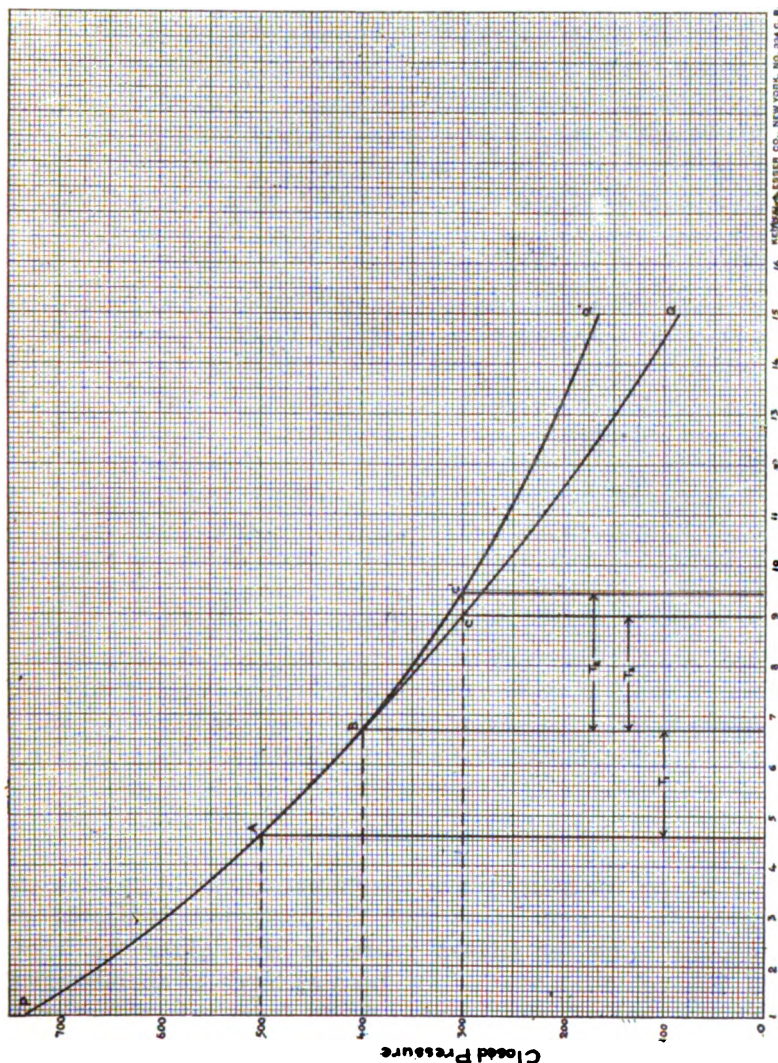


Figure 1.

and this introduces the further difficulty as to the type of tests available. Of these tests, three are in general use: Open

Flow Capacity, Closed Pressure, and Minute Pressure Above Line.

The open flow capacity tests may as well be eliminated as a possible basis for accurate valuation. The senior author, in his experience in appraising many gas properties, has found few with sufficient tests of this type to warrant their use and the method is being rapidly discarded for more economical ones. In any event these tests can be used with greater ease than perhaps any others, and where no closed (rock) pressures or minute pressures are available, should form the basis of all estimates. Their application is not the subject of the paper.

Having found only closed rock pressure and minute pressure above line data on every appraisal made, it was necessary to develop a suitable means for determining reserves with these tests at hand. Minute pressure above line tests are adaptable for the purpose to a limited extent only, firstly, because the line pressure is not uniform throughout the well life and second, because the tests furnish an estimate of daily capacity against operating conditions and not actual capacity. This latter fact was demonstrated for one large gas company and was largely instrumental in the development of the more satisfactory method to be described. A number of wells were turned into the line only at times of the year when the closed pressure was favorable to the line pressure. As a result, the effective minute readings were practically the same for many years. The number of wells showing this condition were too great to advise use of minute pressure. In appraisal the consequence is evident, since the size of the well determines future reserves and therefore valuation, with the effective pressure uniform for many years, the valuation would be constant irrespective of age. One case in particular indicated no change in value for fifteen years, or throughout its whole life. The valuation would have been as large at abandonment as at the time of completion. Aside from this objection it must be recognized that the tests are inaccurate. When used collectively and then corrected by an average yield factor, the amounts found by these readings are satisfactory, but as the basis for the whole appraisal they can hardly be recommended

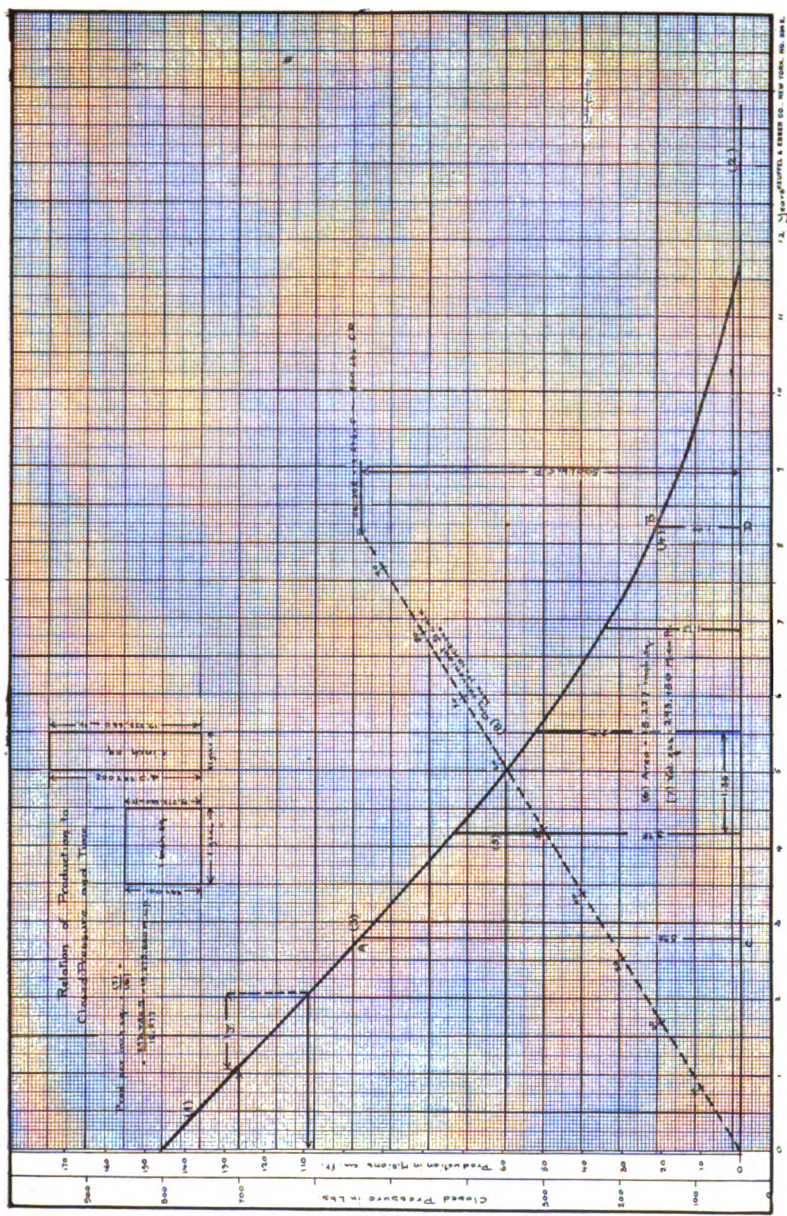


Figure 2.

as productive of results within reasonable accuracy unless carefully considered.

Closed Pressure Tests are most accurate of all. Each well is shut down for short periods every year, making it possible to obtain tests as economically and accurately as desired. But closed pressure is not readily convertible to production, and for valuation we must have the amounts of gas in some unit of cubic feet. An endeavor to find the relation between decline in closed pressure and production brought about the development of the method herein discussed. Previous to this time it has always been assumed that volume of gas in a well is proportionate to closed pressure and therefore production is proportionate to decline in closed pressure. The same assumption is made for the formula given by the Internal Revenue Bureau for use in computing gas depletion. It is based on the relation of pressure decline to total pressure available, which is presuming uniform production per pound decline throughout the life of the well. This is not in accord with Boyle's law, for the amount of gas decreases in a well instead of remaining constant. Further, the volume occupied by the remaining gas is constant in the case of the well, except for water encroachment while in the other case it varies with pressure. The original method, or rather the method now in use, is being called that of Constant Production to the Pound Decline, and not Boyle's method. For convenience the initials C. P. P. D. are substituted when referring to it.

By the use of the theory of constant production per pound decline all the variables incident to gas accumulation and extraction are entirely ignored, and the rate of production recovery is taken in relation to decline in closed pressure. It remains to prove that so simple a relation does not exist in nature. As a portion of the proof depends upon the purpose and type of decline curve herewith presented, the procedure in constructing the curve will be discussed first, and the proof of validity given thereafter.

The principle on which the curve to be described is based is chiefly that *the areas beneath segments corresponding to closed pressure decline are proportionate to the amount of gas produced*. It is to be noted that in the method outlined, the

relation between closed pressure decline and production is one of surfaces and not of volumes. Had volume been adopted, the theory of C. P. P. D. could be recognized as applying to natural gas. Experience and evidence, however, preclude any such recognition. The variables occurring in nature are too numerous ever to yield a uniform amount of production for each pound of closed pressure decline.

A few of the many factors tending to cause deviation from the theoretical rate are:—

1. A gas reservoir is not a closed container. The commodity is perhaps the most mobile natural resource. The limit of migration zone varies with the physical characteristics of the producing horizon, water conditions, and other interferences.

2. Pressure in the reservoir is not uniform. When flowing, the pressure is least near the well and increases with distance therefrom to a point where influenced by interference with other wells.

3. Gas flows against line pressure, which is not uniform.

4 Water conditions are not constant. The amount of water in the sand varies and consequently affects the production. Encroaching water is likely to drown out a well when the closed pressure is still high.

5. A uniform temperature is required to yield results in accordance with the ideal case. A variation in temperature is not at all likely when during the life of the well, change in pressure and other factors are taken into account.

6. Leakage outside of casing to non-producing sands. This is likely to increase with the age of the well and deterioration of equipment.

7. Vacuum—Gas recovered by vacuum cannot be estimated by closed pressure decline. Wells in this stage seldom show any change in closed pressure even though gas is being recovered.

With such a list of variables, many of which differ with each well and sand, it is not safe to attempt estimates on individual wells. Data had best be grouped and average conditions found. Moreover, for the particular curve to be demonstrated, part of the individual wells produce as follows:—

Sands or Combinations	No. of Wells
1. Fifth	8
2. Gordan and Fifth	10
3. Gordon Stray and Fifth	5
4. Gantz, Gordon and Fifth	3
Thirty Foot, Fourth and Third, etc.	1 etc.
Total 22 combinations—10 sands—71 wells.	

Because of the very great amount of work which is required

to estimate future production for each well when the combinations are so numerous, the grouping by pools or geographical divisions was found most practicable. However, it

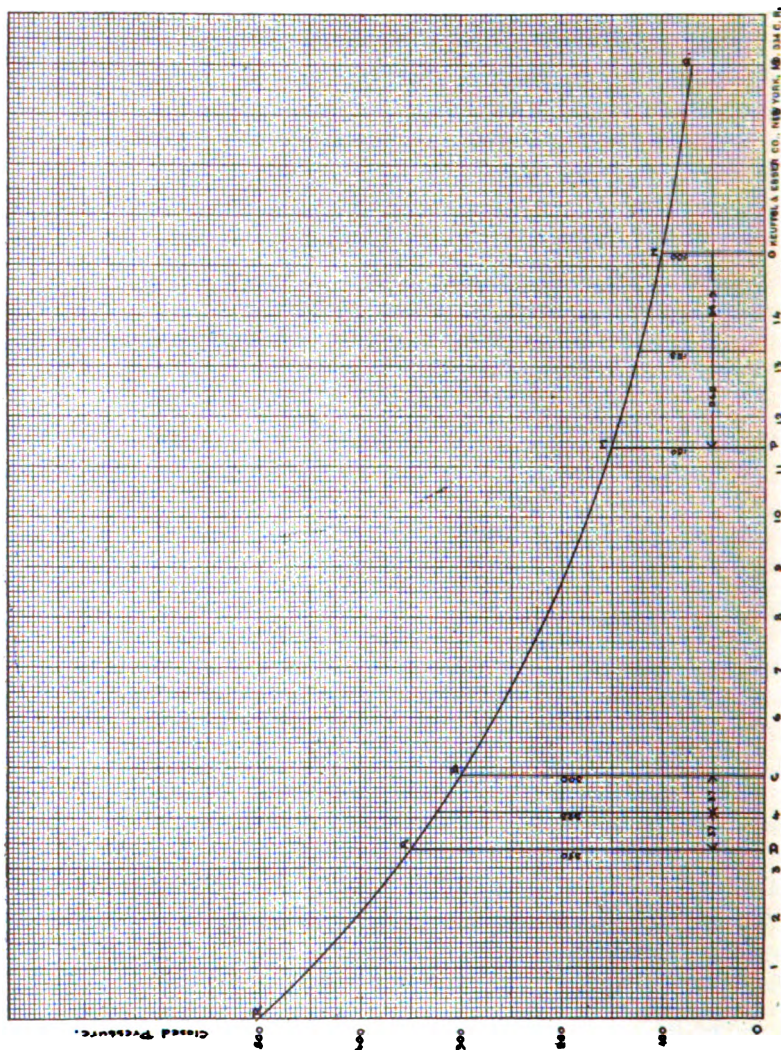


Figure 3.

must not be assumed from this that individual well curves, based on individual well data cannot be devised. This is a problem for the engineer to solve.

Figure 1 is submitted to show that the area corresponding to a closed pressure decline is proportionate to the amount of gas produced, and that volume is not proportionate to the decline in closed pressure.

The line PQ represents the Closed Pressure Decline of a well not in accordance with C. P. P. D. The segment AB is the decline from 500 pounds to 400 pounds, and T' the time consumed in declining. Through AB is drawn a curve PQ' of equal area face for constant decline, namely, a curve agreeing with C. P. P. D. Curve PG intersects the 300 pounds Closed Pressure Line at C, and PG' the same line at C'. Since the curves both go through AB the volume corresponding to the decline will be the same in both cases. Assuming an average closed pressure from A to B of 450 pounds and a resulting effective minute pressure above line of (x), the volume of gas produced during the decline of 500 to 400 can be obtained. The surface representing this volume is designated as ABMN.

By the same procedure the volume corresponding to the decline from 400 to 300 pounds can be determined. This is the effective minute pressure times the volume and the time. The effective minute pressure will be equal in both cases, as BC and BC' both decline the same amount, the the average closed pressure is 350 pounds. However, the time element affects the volume of gas produced in the period. Effective minute pressure (Y) times volume of hole (Z) times time (T) equals amount of gas produced. Y and Z are equal for each case, but time is different. For BC' the time is T_2 and for BC it is T_3 . Thus, the volume of gas produced by well PQ' is declining from B to C' is YZT_2 and well PQ is declining from B to C is YZT_3 . The ratio between the volume of gas produced is T_2/T_3 and the same ratio holds for the surface BC'RN to BCON. Therefore, it can be assumed that the surface enclosed by the closed pressure decline is always proportionate to the amount of gas produced, and by ascertaining the relation of one of these surfaces to a known volume of gas, a scale can be adapted. This scale will be true for any surface and volume enclosed by the closed pressure curve.

All references in the outlining of the method are to Figure

2, and are taken up in the order necessary to construct the curve, which is:

1. Closed Pressure Composite Decline Curve.
2. Line of Economic Limit
3. Average Beginning Closed Pressure of Wells.
4. Average Final Closed Pressure of Wells.
5. Vertical Distances.
6. Surface.
7. Volume of Average Sand.
8. Line for Scale Computation.

1. *Closed Pressure Composite Decline Curve.* This curve is nothing more than the usual average or composite curve of a number of wells. The method of constructing this is optional with the engineer. A number of recognized ways are in common use. Some are not practical because of the nature of closed pressure decline data. In all the appraisal work done thus far, satisfactory results have been obtained by using the so-called Segmental Method.

2. *The Line of Economic Limit.* This depends upon the history of abandonment. In the particular case shown, the wells in the region had been abandoned, on the average at forty pounds closed pressure. It is quite possible that in the future, when vacuum is installed, a much lower average will result. Where such is likely to occur, the line can be lowered to the probable average future pressure of abandonment. Since no production takes place below this line it is considered the line of zero production.

3. *Average Beginning Closed Pressure of Wells.* For all the wells used in the construction of the composite decline curve, the beginning closed pressure is listed and the average found. Since it is necessary to have production data, for the period corresponding to closed pressure decline of each well, the readings do not all go back to initial pressure. The average herein was 540 pounds, or 500 pounds above the line of economic limit. The 540 point is indicated on the composite curve as the point of beginning of the average well.

4. *Average Final Pressure of Well.* This is the average of the last readings used for all wells included in the composite curve. It is not necessarily the readings as of the last date available, for production must be given, and consequently the

last reading used for some wells is not the most recent. The average was 149 pounds or 109 above the economic limit. The point is marked on the curve as in the case of the beginning closed pressure.

The production for each well is tabulated, as are the number of sands. The results obtained from a table devised to get this information are:—

	No. Wells	No. Producing Sands	Beginning C. P.	Last Reading C. P.	Production all wells for the M. Cu. ft. Period
Total Averages	119 1	199 1.7 per well	64,266,540.05	17,792, 149.05	54,370,850. 498,940

There is now given the average beginning closed pressure, the average final closed pressure and the production for the period. The production is given for the average well, and for the time indicated by the average decline. For purpose of refinement it is desired, often, to find the production for the average sand, instead of for the average well. All data in this report are reduced to one sand.

It is assumed that the area beneath the segment AB, and above line of economic limit, or ABCD, represents production for the average sand or well. The area has to be calculated. For this, Simpson's rule is used although a planimeter or any other method of obtaining area is satisfactory.

By the rule, the base CD is divided into an equal number of parts, as (5) of Figure 2; the ordinates corresponding to the division points drawn and lengths then found. The formula is:—

$$\frac{1A \text{ plus } 4E \text{ plus } 2O \text{ plus } 1N}{3} \quad \times \text{ Dist. equals Area}$$

Distance being the spacing of the ordinates. The first (A) and last (N) ordinates are always multiplied by one, the other odd ordinates (O) by two and the even ones (E) by four, the sum is divided by three and the result multiplied by the dis-

tance between two consecutive ordinates. In the example only four equal parts are made and the formula is, therefore:—

$$\frac{1A \text{ plus } 4B \text{ plus } 2C \text{ plus } 4D \text{ plus } 1E}{3} \quad \text{X Dist.}$$

The computation is:—

$$\frac{(5.00 \times 1) \text{ plus } (3.75 \times 4) \text{ plus } (2.71 \times 2) \text{ plus } (1.77 \times 4) \text{ plus } (1.09 \times 1) \times 1.36}{3}$$

equals 15.227 square inches

The average volume per well was found to be 498,915 M cu. ft. divided by 1.7, the average sands per well, gives 293,480 M cu. ft. per sand. This amount corresponds to the surface ABCD or to 15,227 sq. in. The production per inch square is 293,480 equals 19,293. 6 M cu. ft.

On the chart, time in years, and each 100 pounds of closed pressure are one inch apart, making 100 pounds for one year equivalent to a square inch, or 19.273 M cu. ft. Had years been a half inch apart the same volume would be equivalent to 200 pounds, provided the length of the curve represented 24 years and not twelve.

8. *Line of Scale Computation.* Since one hundred pounds is too small to fix the scale, the amount has been multiplied by five. The corresponding production for five hundred pounds is 96,368 M cu. ft. On a scale or a sheet of paper with decimal divisions, a length equivalent to 96,368 M cu. ft., or 9.637 inches is taken. The zero point of the scale is placed at the left end of the line of economic limit and swung around until the 9.637 point is opposite the 540 Closed Pressure point, that is 500 pounds above economic limit. Each inch laid out on the line represents ten million cu.ft. Mark the points, and by horizontal lines construct the production scale along the left margin of the graph. Thus there is given a closed pressure, and a corresponding production scale.

To Read:—A sand with an average closed pressure of 700 pounds for the years is producing at the rate of 126,000 M cu. ft. per year. It will produce 119,00 M cu. ft. the following year and 82,000 M cu. ft. the third year, etc. In the first case the amount shown at 700 is the production for the year, and in the second, one horizontal inch from the intersection of 700

line with the composite decline curve is the production, and so on for each successive year.

Where no closed pressure is given for a well the rate of

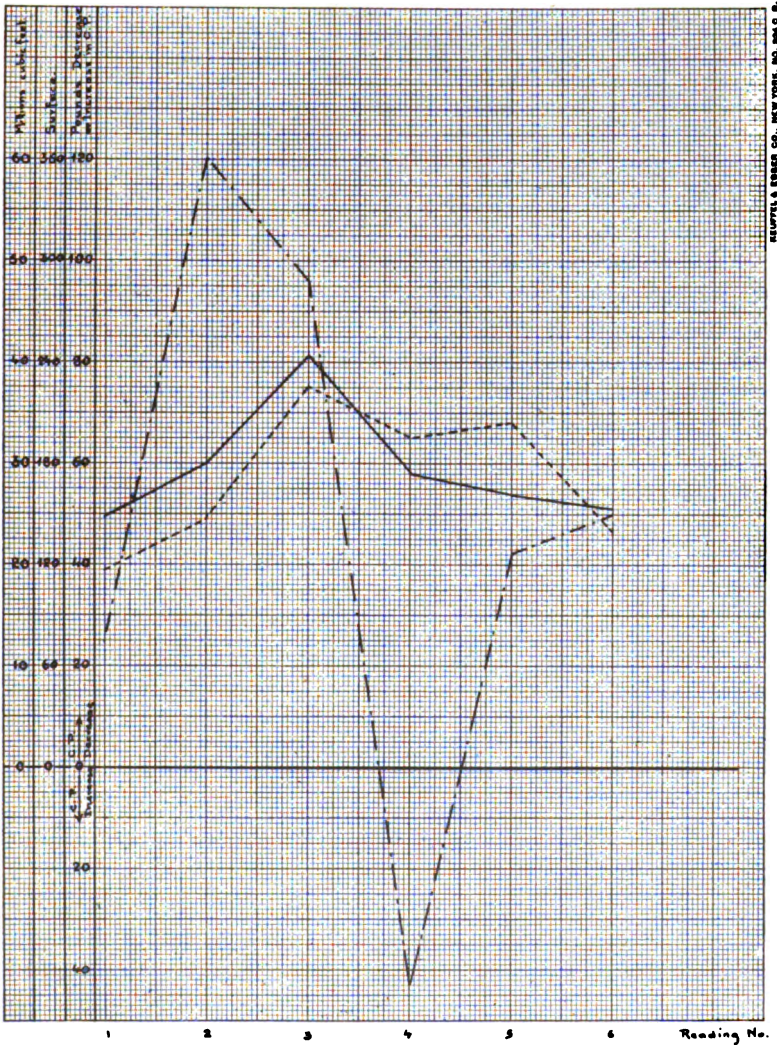


Figure 4.

production for any year will serve equally well. It must be remembered that the production used in constructing the curve

is on minute pressure above line estimates, and any results obtained are subject to correction to the equivalent of metered production. The same holds true where open flow tests are used to make this estimate. If meter readings are available, no correction is of course required.

PROOF OF METHOD

The proof necessary, in order to substantiate the contention that volume is not proportionate to decline in closed pressure, must show: (1) The area relation for well of constant production per pound decline. (2) That for individual wells the relation of production to area embraced by closed pressure change is more accurate than that of constant production per pound decline. (3) That total estimated future production of wells by curve corresponds on the average with the actual production recovered from the wells. (4) The rate of return of production by curve corresponds with rate by actual wells. The proofs will be taken up in the order outlined.

Proof 1. Area Relation for Well of C. P. P. D. The first essential in this proof is to develop a curve which declines consistently with the rule, and therefore produces the same amount of gas for each pound decline. Having found such a curve, the next step is to prove that the areas beneath two segments of the curve, each segment representing the same number of pounds decline, are equal. In the discussion to follow the C. P. P. D. curve is constructed, then the area is computed to show its relation to production.

Assume a well of volume V_0 containing gas at a pressure P_0 . The gas is allowed to escape. The amount of gas escaping is proportionate to the effective pressure of the gas in the vessel to the size of the orifice, the nature and viscosity of the gas, the friction between the orifice and the flowing gas, ect. These latter are all small quantities and can be considered as constant factors, the sum of which is K . The amount of gas escaping per unit time is therefore KP .

After one unit of time, the pressure has declined from P_0 to P_1 due to the amount of gas, KP , which has escaped, and based

on the fact that the total quantity $V_0 P_0$ is constant. Therefore:

$$V_0 P_0 = V_0 P_1 \text{ plus } K P_0$$

$$\text{or} \quad \frac{P_1 = (V_0 - K) P_0}{V_0}$$

$V_0 P_0$ equals $V_0 P_1$ plus $K P_0$ is a general formula. This can be used further for the second unit times as:—

$$V_0 P_1 \text{ equals } V_0 P_2 \text{ plus } K P_1$$

P_2 being the pressure after the second unit of time as resulting from the new amount of gas escaped $K P_1$.

$$P_2 = \frac{V_0 - K}{V_0} \times P_1 \text{ or } \frac{V_0 - K}{V_0} \times \frac{V_1 - K}{V_0} \times P_0$$

$$P_2 = \frac{(V_0 - K)n}{V_0 \quad n} \times P_0 = \frac{(1 - k)n}{v} \times P_0$$

Let P_0 equal 100 pounds, V_0 equal 1000 cu. ft. and K 100, using the formula:

$$P_n = \frac{(1 - K)^n P_0}{V_0}$$

We get the following data for P :—

P_0 equals 100
 P_1 equals 90
 P_2 equals 81 etc.

In the Closed Pressure Production Method it has been assumed that the amount of gas produced by a well depends on the typical condition of the well's decline and is *proportionate to the area* enclosed by the closed pressure line, the bottom axis and the two ordinates corresponding to the beginning and final closed pressure. And this is true for any kind of actual decline curve.

By the C. P. P. D. rule for 10 pounds closed pressure decline there should correspond the same amount of gas, whether the well decline from 70 to 60 or from 40 to 30. By the Closed Pressure Production Method, the surfaces are proportionate to the volume; the surfaces should therefore be equal for the same decline.

The closed pressure decline curve calculated according to the rule has a definite shape.

$P_n = K^n P_0$ is the typical logarithmic curve.

Furthermore, the curve is asymptotic to the zero closed pres-

sure line. It is possible to change K to P^0 and get a series of C.P.P.D. closed pressure decline curves. But if two points of the curve are known, the whole curve is perfectly definite,

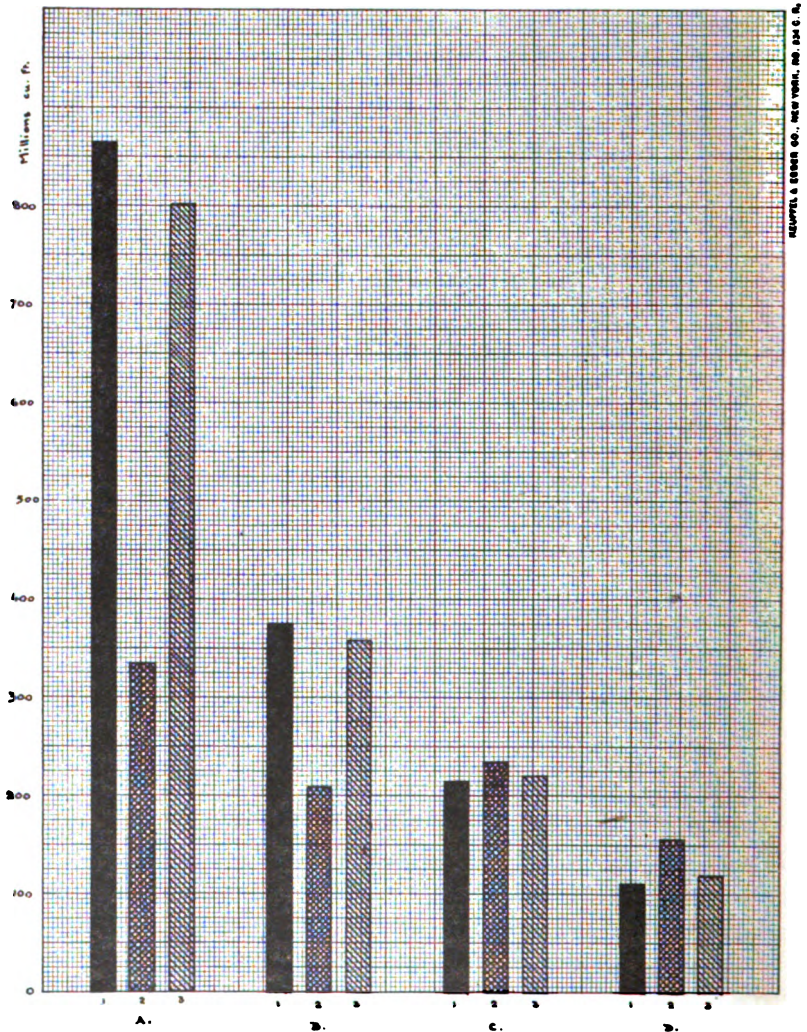


Figure 5.

and a definite value for K and P is obtained. Under such conditions, if it is known that the well decline from 70 to 60

pounds pressure in .74 years, the remainder is readily ascertained. By formula it has to decline from 60 to 50 in .85 years. Does it have to decline in such time by the simple fact that it declines from 70 to 60 in .74 years? Ten wells each declining from 70 to 60 in .74 years will decline from 60 to 50 in ten different ways. And also, the production is different for each of these wells because the time to decline is different. Moreover, it is shown by the Closed Pressure Production Method that there is strong relationship between the production and the time of decline, and the shape of the decline curve.

Proof 2. For individual wells the Relation of Production to area by Closed Pressure Change is better than that of Constant Production the Pound Decline. Although the individual well data are likely to be incorrect, they are herein used to demonstrate the relation surface bears to change in production.

A number of wells have been taken, and production for varying periods of decline determined. Given these closed pressure declines and corresponding production, estimates of reserves per unit were made by the C.P.P.D. method and by the area method. For each method the same information is taken as a basis. An economic limit of forty pounds is applied to both.

The final results in the table are obtained by comparison of estimates for the short periods of decline with the average of the whole. In any estimation of reserves, be it by the amount per pound decline or unit surface, the amount must necessarily be an average of the whole.

The details in getting the results are too lengthy to describe in this paper. They will be submitted on request to any who are interested.

The graph, Figure 4, shows one case. It merely indicates a strong relation between area and production. In nine cases checked it was found that the area relation was many times more accurate than the assumption of uniform production per pound decline.

Proof 3. That the Total Estimated Production of Wells by Curve Corresponds, on the Average, with the Actual Pro-

duction of the Wells. An effort is here made to show that the estimate future production of a number of wells, as read from the curve, compares favorably with the amount of gas actually recovered from these wells.

To do this, three counties in West Virginia were chosen at random. Accurate production and closed pressure records were obtained and the following procedure was carried out: (1). Closed Pressure Production-Composite Decline Curves, were made according to the procedure outlined in this article. (2). Given the initial closed pressure of a number of wells as of an early date, an estimate was made of their probable future, and the amounts tabulated. (3). For the same wells given in (2) the actual production for the life of the well was totalled. Where a well was not yet completely exhausted, allowance was made for the remaining production by estimating from the curve. This is, in most cases, but a small per cent of the amount already extracted. (4). With the same data used in constructing curves in (1), the amount of production per pound decline was found and the ultimate reserves secured by this method of estimation.

Here is a comparison of the final results, showing how much estimation by area method and C.P.P.D. varied from the actual ultimate production :

County	District	Percent Error Area Method	Percent Error C. P. P. D.
Taylor	Booth's Creek	7 High	40.7 High
Tyler	Centerville	3 High	11.5 High
Lewis	Courthouse (Wells over 500 lbs.)	7.1 Low	61.4 Low
Lewis	Courthouse (Wells over 500 lbs.)	4.4 Low	44.4 Low

Wells of above and below 500 lbs. were taken in one county to see if size would affect the results.

It is certainly apparent from the above facts that production is not proportionate to decline in pressure. The error is far too great to warrant favorable consideration of the method. In fact, known errors of possibly sixty percent, as in the case of one county, are absolutely prohibitive. To attempt an appraisal with the main premise no more than a guess is indeed careless and would lead to unreliable results.

Proof 4. That Rate of Return of Production by Curve Corresponds, on the Average, with the Actual Rate. The engineer, in any valuation, is interested to know whether (1), the total estimate of reserves is within reasonable accuracy,

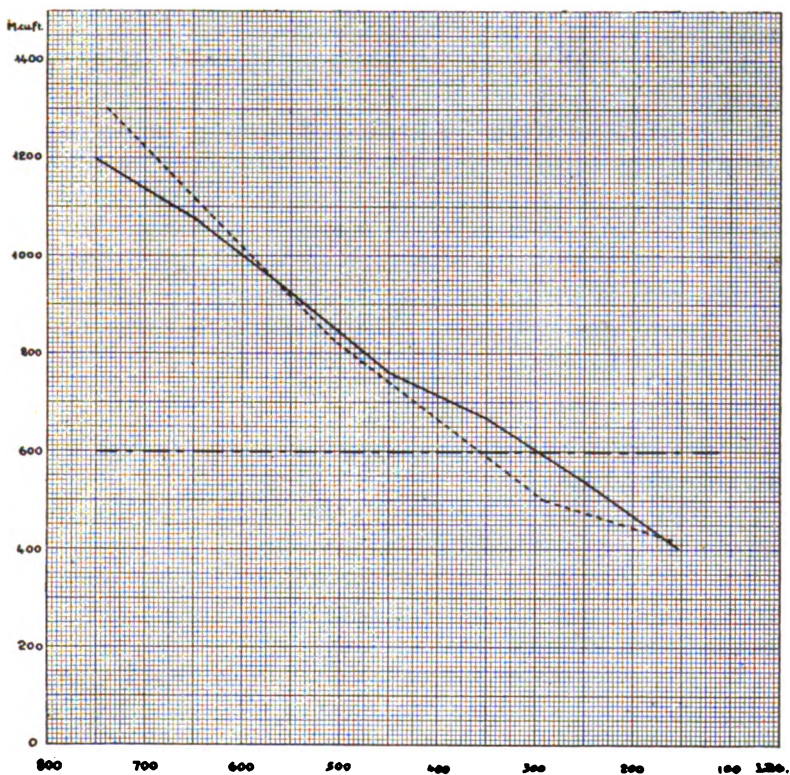


Figure 6.

and (2), whether the rate at which the reserves are calculated to be returned is correct. Proof of the former has just been demonstrated. The latter is of great importance, as present value of a well depends upon the future price, operating cost and discount. Thus to place more production in any one year than is properly assignable to it would cause the amount in error to be wrongly priced and discounted.

To prove the validity of the curve in respect to rate, the production per pound decline in various stages of well life

was examined for a number of wells. Then a comparison was drawn, with the amount the curve indicates as production per pound for each period. It has been found that the production per pound during a well's life may decrease, increase, or both, or it may be nearly constant. By its shape the composite decline curve controls the rate at which the gas is returned. It is of course, a theoretical one and made up of averages.

In Figure 6, is given the estimated production per pound loss in various stages of a well's life as predicted by the composite decline curve. For comparison the actual production of wells in the field is given in a similar manner. The dot-dash line represents rate of return estimating an assumption of uniformity of production per pound loss. This check shows a remarkably analogy between the estimates by the curve and the actual condition.

CONCLUSION

For the region under consideration, the various proofs have demonstrated that:

- (1) The relation of production to closed pressure is not uniform except in accidental instances.
- (2) The ultimate reserves as estimated from the composite curve herein recommended are within reasonable accuracy for use in annual analytical appraisal work.
- (3) The estimate of future production by years from the composite curve would, on the average, correspond with the actual production.

These essentials must not be overlooked in an appraisal. The foundation for any valuation report is the estimation of expected future returns. An erroneous prediction of reserves makes unnecessary any subsequent refinements. In fact, if the rate of return is not definitely ascertainable, a valuation by using yearly production amounts is hardly justified.

On account of the great divergence in "pull," sand conditions and other factors incidental to the amount and rate of recovery it is better to be pessimistic over the results obtained in this paper. Rather than assume predictions based on a Closed Pressure Production Curve as infallible, it would be

better to make checks and determine the applicability of the method for the region under examination. It is hoped that this paper will serve to develop methods of estimating reserves for gas wells which are reliable and adaptable to the conditions prevalent in the operation of natural gas properties.

It is felt that in natural gas estimations, one must, because of the nature of the records and the custom in operating wells, resort to averages taken from wells producing under similar physical conditions. Perhaps with further research it will be possible to apply correction factors to individual well data which will make possible the prediction of future reserves in gas as well as in oil. However, for the present enough experiments have not been performed to demonstrate a feasible individual method and therefore, an average method of proven capabilities must be the foundation for all valuations.

CERTAIN RELATIONS BETWEEN PRODUCTION AND STRUCTURE IN NORTHEASTERN OSAGE COUNTY, OKLAHOMA

BURTON HARTLEY¹

Investigation extending over several years, of the northeastern part of Osage County, Oklahoma, the adjoining portions of Chautauqua County, Kansas, and Washington County, Oklahoma, have brought to the writer's attention a great lack of uniformity in the relation of oil and gas production to structure. To date most geologists in casually referring to the area and attempting to explain the idiosyncracies of oil accumulation have leisurely dismissed the question as a matter of "lensing the sands." While such a condition probably does exist there appear in numerous instances to be a number of more fundamental reasons for the irregular occurrence of oil pools.

Production in this area is almost entirely confined to the section above the "Oswego" lime and a brief enumeration of the sands and limes, their occurrence and correlation will be given.

The "Big" lime (Oolagah), is in reality made up of two limes, the Pawnee and Altamont of the Kansas section, separated by the Bandera shale. Progressing south the shale thins rapidly and these two limes converge, until in T. 27 N., R. 12 E., Oklahoma, they are separated by a few feet of shale locally turning to sand. In the interval made up by the Bandera shale a productive sand generally occurring directly underneath the Altamont lime is known as the Hancock sand in Chautauqua County, Kansas, and as the Weiser sand in Montgomery County, Kansas. This sand apparently carries only water in Osage County.

About 100 feet above the Altamont lime is the Lenapah or "Little" lime. The interval consists of the Nowata shale and carries the most productive sand of the area. This sand has

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various names in different localities. In Washington County it is known both as the Ramsey and Wayside sands, in Chautauqua and Osage Counties as the Peru sand. This Peru sand should not be confused with the Peru sand of the south-

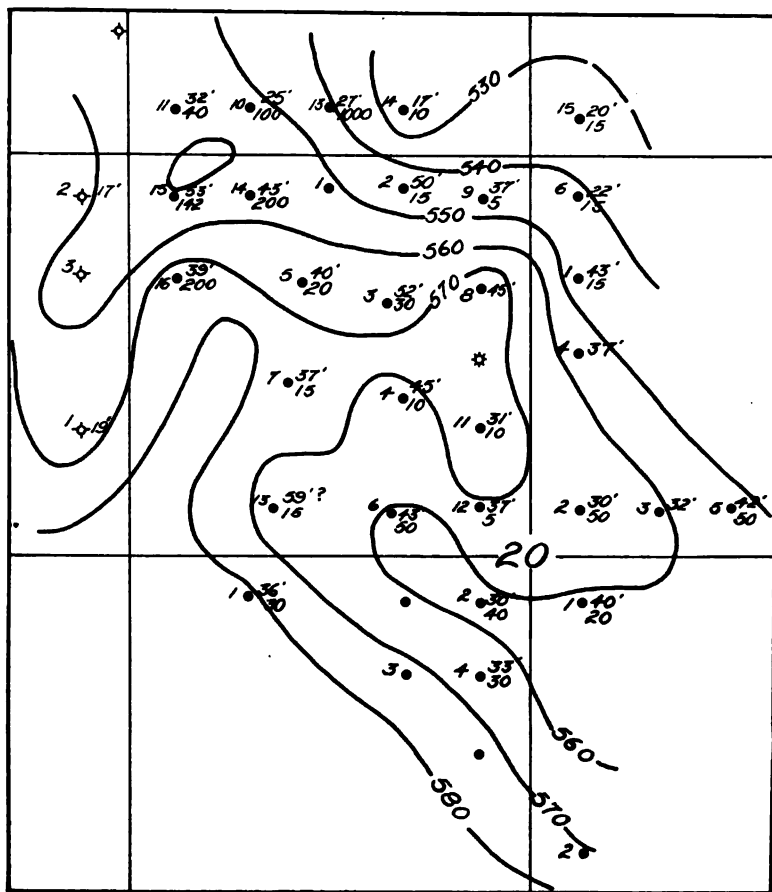


Fig. 1. Small pool in Sec. 20, T. N., R. 9 E., Osage Co., Okla. Contours on top of Peru sand. Figures at right of wells indicate thickness of sand and initial production.

ern Osage and Creek Counties, Oklahoma, which lies between the Pawnee and the "Oswego" limestones. Also, the Peru sand occurs under the "Oswego" in the southern Osage and is frequently confused with the Peru of Oklahoma. The dual use

of this name for two different sands is unfortunate and this lower sand would better be referred to as the Peru of Oklahoma. The Kansas appellation was derived from the town of Peru in the heart of the oil fields where this sand was first encountered while the Oklahoma name was given through a miscorrelation. It might be remarked that the same Nowata shale carries the Whiting and Cleveland sands farther south and they all might be correlated in a long distance manner as one and the same. Production above the "Little" lime is not relevant to the purposes of this paper.

While working out the facts and the conclusions arrived at in this paper a large number of individual pools were studied. It is not possible to reproduce maps of all of them so a number of particular pools that best represent the peculiar conditions encountered have been selected for special description.

In section 20, T. 29 N., R. 9 E., Osage County, Oklahoma, there is a small pool covering approximately three hundred acres. The surface structure across this pool is a straight west to southwest dip and there is no surface folding in the vicinity to which this pool could be related. Figure 1 shows the subsurface structure constructed upon the top of the producing sand. Subsurface contours drawn upon the top of the Lenapah "Little" lime and an upper water sand show minor variations but are essentially the same as to general features. Thus we see that the sand body has a structural form similar to an embayment or lagoon protected by an outer barrier in the form of two structural noses, one extending to the northwest and the other to the southwest. Continuing the comparison with a lagoon we see that the sand body is thickest along the shoreward edge and thins outward to the channel. On the seaward side the sand rapidly plays out. Landward, from the interior edge of the lagoon, the sand rapidly thins out and disappears; a well one half mile east of No. 6 (NW cor. sec. 21) reports no sand whatever. It will be noted that the best production was obtained in a narrow strip in the lee of the northern barrier.

The Barnsdall pool covers about four hundred acres in the northeast quarter of section 35, T. 29 N., R. 11 E., Osage

County, Oklahoma. Surface structure shows no folding of importance. Figure 2 shows the subsurface structure with contours constructed upon the top of the Lenapah "Little" lime which immediately overlies the producing Peru sand. Contours upon the sand and upper water sand are virtually the same. Again we see the embayment feature of the producing

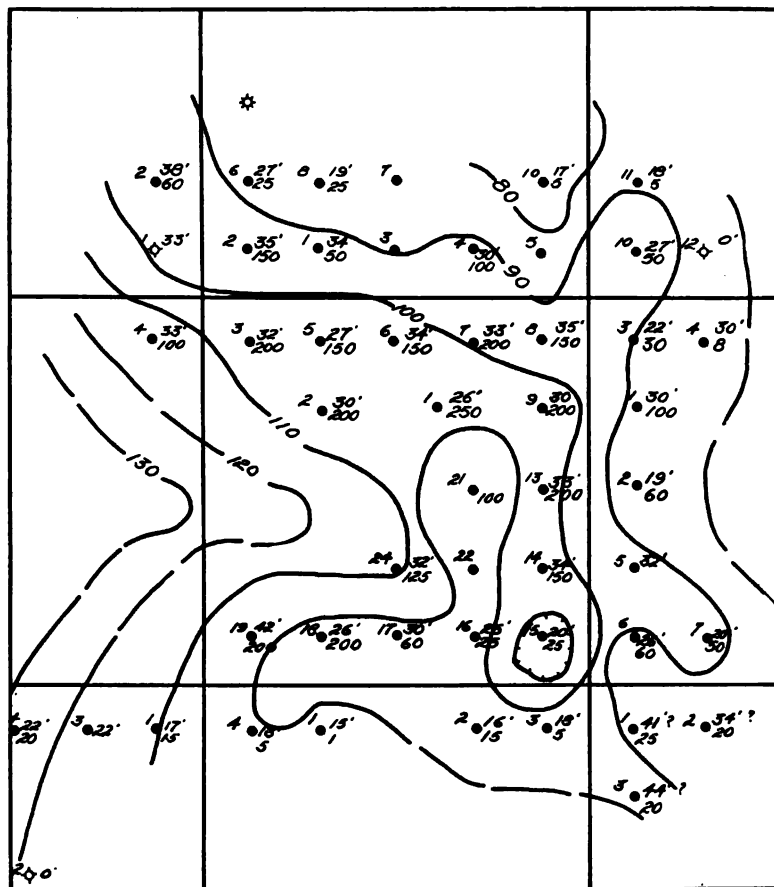


Fig. 2. Barnsdall pool T. 29 N., R. 11 E., Osage Co., Okla. Contours on top of Lenapah Lime.

area, although there is preliminary evidence that the major portion of the pool lies between two local structural "highs. The sand body is thickest in the basin and thins rapidly shore-

ward to the north, south and east. The best production was obtained in a narrow belt roughly parallel to and considerably away from the shoreward facies.

Several miles to the north of the Barnsdall pool there is some scattered development just south of the Kansas line. Figure 3 shows the subsurface structure of this area with contours constructed upon the top of the Lenapah lime. Production seems to be confined to synclinal areas, the sand being cut out higher on the structures and being broken deeper in the troughs. Viewed from a topographic rather than structural standpoint, these two producing areas have the appearance of old river channels, or the deep arms of a bay. Production and sand thickness apparently follow no system. Surface structure in this area generally shows a long nose extending from section 14 westward across section 15, a synclinal area in the southwest of section 22 and another in the northeast of section 21. This surface structure bears a fair resemblance to the subsurface structures in section 22 but very little to that in sections 14 and 15.

In sections 14, 15, 22 and 23, T. 29 N., R. 9 E., Osage County, Oklahoma, and extending northward into Kansas is the Elgin pool. This pool is about one half mile wide at its greatest extent and narrows to several locations at the ends. The pool extends due north and south for over three miles and is clearly a lenticular sand body presumably on the seaward face of a cliff of some size. The sand body is thickest in the center and thins rapidly east and west, cutting out completely from a thickness of 36 feet to nothing in one location. Surface structure shows a slight southwest plunging nose across the center of the field.

The Ramsey pool in T. 29 N., R. 12 E., Washington County, Oklahoma, may be briefly cited. Production lies in the synclinal area between a long plunging anticline on the northeast and a smaller fold on the edge of Osage County. The sand is absent up the flanks of the folds.

One more particular case will be referred to before passing to causes. Twps. 28 and 29 N., R. 10 E., constitute the Belmont area. Well records here are very meagre and it was not possible to develop a satisfactory structure map on the

Peru sand. Contoured upon the top of the Mississippi lime the area shows a very large dome extending slightly west of north through section 34 and sections 2 and 3. On the west side of section 35 and the east side of section 34 is a broad synclinal area just east of the dome. Production in the Peru sand is confined to this synclinal area. The highest parts of

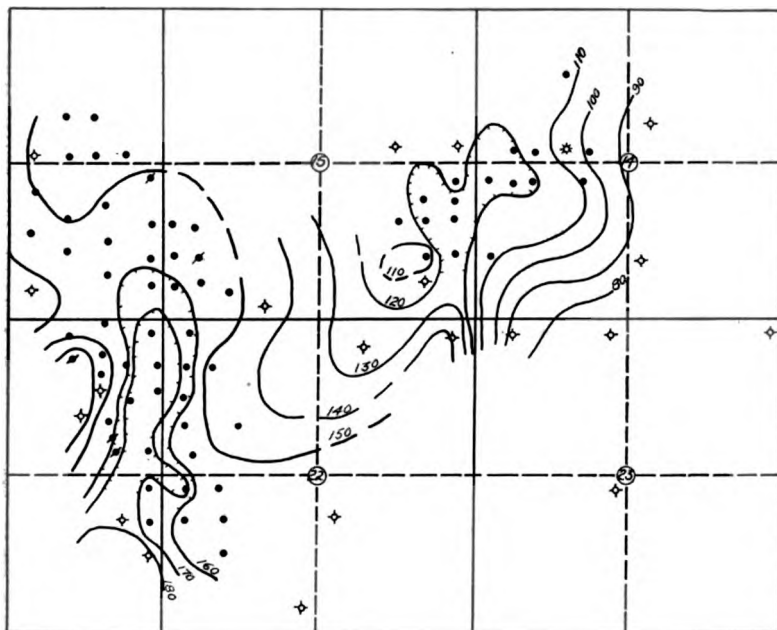


Fig. 3. Part of T. 29 N., 11 E., Osage Co., Okla. Contours on top of Lenapah Lime.

the structure have been productive of gas only from a horizon at the top of the lime. This gas is usually from a gravel or shelly stratum and the only sample which has been observed has the appearance of a conglomerate.

Such conditions as have been outlined above involve a number of causes any of which might be the critical factor. These causes include an eroded and folded Mississippian floor, folding during deposition of the Pennsylvanian, settling of the earlier sediments and a very shallow Pennsylvanian sea with a rapidly oscillating shore line. An outline of the geologic history of this area probably would embrace all of these

causes as contributing factors. At the beginning of the Pennsylvanian there already existed an eroded and folded Mississippian basement, the outstanding feature of which was the Belmont structural uplift. On and around this was a light mantle of fragmentary material, the products of its own breaking down. As the Pennsylvanian sea advanced from the south Belmont stood out for some time at least as an island and was the controlling feature of the currents in these waters on the seaward side. At this time there already existed a topographical trough or basin extending to the north between the ancient land masses of Siouxia and Ozarkia and up which the early Pennsylvanian sea advanced. The sediment brought into this basin by the streams carrying the run off from these old lands were subject to sorting by shore and sea currents and other agencies. The thickness and extent of sand bodies would vary according to distance from the shore, irregularities in the floor, configuration of the shore line, depth of the sea and change in water level. Obviously then there were in this embayment area perfect conditions for the irregular deposition of sands which accumulated in old stream channels, in smaller protected embayments off from the main basin, anywhere in fact except upon top of the small structural folds, already formed in the Mississippian strata and intensified in the Pennsylvanian and which were not covered by waters at that time.

A summary of the conclusions arrived at in the study of many pools is that surface structure in the form of an application of the anticlinal theory is a poor guide to the location of new oil pools in this area. Most of the production is synclinal and therefore presence of an anticline or dome is not the only factor to be considered. It is believed, however, that production bears a relation to structure in that it occurs on the flanks of local folds or in the synclines between them. Very rarely has it been noted that production occurs in small local depressions without adjacent structural uplifts. Geologists investigating this area would probably arrive at more positive results by studying the early Pennsylvanian paleogeographic conditions through the medium of well logs than by merely hunting structure.

JOHN L. RICH: I should like to ask whether or not the sand which is productive in the synclines between anticlinal noses is present on the adjacent anticlines. Farther northeast in the shallow fields of Kansas there are several oil pools occurring under conditions similar to those described by MR. HARTLEY, but the productive sand is present in full thickness on the adjacent uplifts, or anticlinal noses. It is, however, either barren or occupied by small amounts of gas.

BURTON HARTLEY. It is variable, being present sometimes, and sometimes not, though the horizon can usually be recognized and traced. The sand is very rarely present in full thickness and is almost always badly broken.

J. ELMER THOMAS: I was much interested in Mr. Hartley's wide correlation of the Peru Sand. With reference to the Peru Sand which he mentioned, I have a suggestion for the consideration of the geologists. I would favor abandoning the term Prue and refer to that sand as the Squirrel. The Prue is, of course, below the Oswego and has no relation to the Peru but it is very often confused by operators and field men because of the similarity in pronunciation. The Prue sand is the same as the Squirrel and the latter name would seem preferable to prevent confusion with the Peru whose production is more widespread and which is much better known to the oil men.

GEOLOGICAL NOTES

OIL IN IDAHO?

A geologist advocating a search for oil in Idaho is apt to be classed either as a mild lunatic or as a joker with a distorted sense of humor. The mineral wealth of the State is well recognized, but petroleum is commonly omitted from the list of the State's natural treasures. In short the idea that prospecting for oil is unjustifiable has become firmly established that there has been little drilling for oil done in the State outside the Valley of the Snake near Payette, where large but short lived flows of gas were obtained.

It must be admitted by even the most optimistic geologist that about two-fifths of the State cannot, by any stretch of the imagination, be considered possibly oil bearing, since intrusive or metamorphic rocks are known to lie at or close below the surface. However, this leaves about 50,000 square miles, an area larger than the State of Pennsylvania, that cannot so summarily be placed in the non-oil category. Much of this 50,000 square miles is surfaced by lava flows, Tertiary lake beds, and stream deposits which reflect only slightly, or not at all, the structure of the underlying older beds, and wildcatting in these parts of the State will therefore be largely a blindfold proposition, but until extensive wildcatting has been done the region must be admitted to be at least possibly oil-bearing. Furthermore, there are parts of the State, notably in the southeast corner, where neither volcanics nor Tertiary sediments interfere seriously with the search for structure suitable to cause oil accumulations.

The search for oil involves very precise geologic work. Fortunately the stratigraphic work of Schultz, Pardee, Richards and G. R. Mansfield of the United States Geological Survey furnishes a solid foundation upon which to build the more elaborate edifice of minutely detailed stratigraphic and structural work to meet the needs of petroleum geology. Material increase in the knowledge about structural conditions in southeastern Idaho and their possible bearing on petroleum resources has come through the work of Virgil R. D. Kirkham of the Idaho Bureau of Mines and Geology, whose bulletin on "Petroleum possibilities of certain anticlines in southeastern Idaho" was recently issued. This bulletin, which covers parts of Teton and Caribou counties describes a number of pronounced anticlines, but by no means all that are known to be present in southeastern Idaho.

Oil, if present in southeastern Idaho, will probably be in Jurassic, Triassic or Carboniferous formations, although there is also a chance for oil in the Cretaceous. The southeastern part of Idaho is intensely folded and faulted and the fear that alteration of the oil has destroyed chances of success probably has deterred some prospectors from seriously considering operations in the State. However, such evidence as is available does not indicate that alteration has progressed so far

as to seriously injure the chances for the persistence of oil. But few analyses of coals from southeastern Idaho have been published, and these analyses are all of Cretaceous coals. The average fixed carbon ratio appears to be about 56, but this may indicate little regarding the extent of alteration in the pre-Cretaceous formations.

In short Idaho contains enormous areas where there is no proof that oil is absent. In parts of the State anticlinal structure is known to exist in beds equivalent in age to strata that yield oil in the adjacent State of Wyoming. This folded region apparently has not been too far altered to prohibit the existence of oil in paying quantities.

K. C. HEALD.

NEW PRODUCING DEPTHS AT EL DORADO, ARKANSAS

Since the publication of two press notices by the United States Geological Survey¹ calling attention to the possibilities of production in the Marlbrook and other formations lower than the present oil-producing Nacatoch sand and suggesting the proximity of other pools, at least two discoveries have been made, renewing interest in the El Dorado field.

In the early part of May, oil and gas were found at a depth of 400 feet below the Nacatoch, and on May 14th, gas production was found in what seems to be the Nacatoch 9 miles north of El Dorado and 100 feet shallower than at El Dorado.

The El Dorado Natural Gas Company's Frazier No. 1 in Section 6, T. 18 S., R. 16 W., made 10 million feet of gas and 2,000 barrels of salt water at 2529 feet. The Magnolia Petroleum Company drilling in Section 5, of the same township, got 50,000 feet of gas at 2518 feet and at 2542 feet considerable salt water.

In E. M. Brown's Goodwin No. 1 in Section 6, T. 16 S., R. 14 W., 14 miles northeast, near Calion, hot salt water and some heavy black oil were found at 2634 feet. This sand may correspond to the 2530-foot El Dorado sand, but if so it dips considerably northeastward. The poorness of the log of this well makes any conclusions very unsatisfactory.

In view of these discoveries a number of wells in the west part of the field are being deepened. This deeper producing horizon has been noted and tested unsuccessfully in about 20 other scattered wells in and near El Dorado field. It lies from 400 to 425 feet below the top of the Nacatoch producing zone, and is generally separated from

¹U. S. Geological Survey Press Notice: Wildcat wells in South-central Arkansas stop short of deep oil sands, April 22nd, 1922, see this Bulletin, pp. 350-358.

U. S. Geological Survey Press Notice: El Dorado oil field in Arkansas not on an anticline, May 15th, 1922, see this Bulletin, pp. 358-367.

a bed of chalk above by a few feet of gumbo. A *Crenella serica*² identified from 2552 feet in the Cooper-Henderson well in Section 19, T. 17 S., R. 15 W., would indicate that this new producing horizon is of Marlbrook age. If this is true then the Marlbrook is about 350 to 400 feet thick and contains thick beds of chalk; 220 feet of chalk having been recorded in the Magnolia Petroleum Company's well, a carefully drilled test already referred to, and 110 feet in the Cooper-Henderson well. Over 100 feet of lime are recorded in the Southern Oil and Land Company's Armstrong No. 12 in Section 31. T. 17 S., R. 15 W., from 2350 to 2450 feet.

If this interpretation is correct then only the small thicknesses of lime, broken with sand and shale, and logged in the deep El Dorado wells as occurring approximately between 2650 to 2750 feet can be assigned to the Annona horizon. If the usual interval of 150 to 200 feet between the bottom of the Annona and the Blossom horizon is allowed, then the sand producing at Haynesville may be expected around 2900 feet in the El Dorado field where the elevation is about 200 feet.

Drilling to a depth of 3,000 feet is, therefore, urged in all wells before abandoning, to test thoroughly the two and possibly three sand horizons below the Nacatoch. No well has ever been drilled in Union County to the Woodbine, or deeper sands, productive in the Caddo, Louisiana, field. The Woodbine at El Dorado may be expected from 3,350 to 3,450 feet.

In Section 8, T. 16 S., R. 15 W., in the northern part of Union County, the discovery of what is presumably the Nacatoch sand structurally 100 feet higher than at El Dorado, makes that territory 9 miles north of the field appear favorable for a new pool. The discovery was made by the Oil Operators' Trust—Murphy No. 1 which blew in unexpectedly with more than 50 million cubic feet of dry gas from a depth of 2024 feet. As no wells have been drilled within less than 4 miles of the Murphy No. 1, the area to be tested is rather extensive. The discovery well is blowing wild and burning intermittently.

V. P. TEAS.

Shreveport, La.
June 9th, 1922.

POSSIBLE SUB-SEA ANTICLINES, GULF OF PARIA. TRINIDAD- VENEZUELA

The basis for the writer's opinion that there are several well developed sub-sea anticlines under the Gulf of Paria, Trinidad, B. W. I. is to be found on the British Admiralty chart No. 483-A, "West Indies,

²U. S. Geological Survey Press Notice. Oil from the Nacatoch sand, El Dorado, Arkansas, February 7th, 1922.

Trinidad Island and Gulf of Paria" by Commander W. Chimmio, R. N., H. M. Surveying Ship "Gannett," made in 1866 and 1868.

Trinidad Island contains numerous well developed anticlines. Some of these are known to be productive of considerable quantities of petroleum. In the vicinity of the "Oropouche Lagoon," longitude 61° 30' west; latitude 10° 11' north, there are no less than nine distinct structural uplifts. The strike of the major axes of these folds varies from due east and west, to south 70° west. The anticlines are generally asymmetrical, the south flank having the lesser angle of dip.

The Admiralty map mentioned indicates sixteen definite strike-ridges existing under the Gulf of Paria. With the exception of four of these sub-sea elevations, the strike is approximately the same as that of the anticlines to be observed on the Island of Trinidad, B. W. I. and the northeastern mainland of Venezuela, S. A.

It is probable that the extensive seeps of petroleum situated about the mouth of the Rio Perdenales, Venezuela, in latitude 10° 02' north; longitude 62° 12' west, are located on a sub-sea fold extending from the Island of Trinidad into Venezuela on the west. The rocks "Soldado," "Pelican," "East," and "Black" exposed above the waters of the Gulf of Paria, are visible evidences of these sub-sea anticlinal extensions in the vicinity of the mouth of the Rio Perdenales. The strike of the uplift is approximately east and west on its submerged eastern half and south 65° west on its western or Venezuelan end.

The elevation of the top of the several strike-ridges above the floor of the Gulf of Paria varies from 30 to 120 feet. The length of the sub-sea ridges varies from fourteen to twenty-one miles. The average width ranges from two to seven miles, the lesser figure denoting the width generally common to the elevations.

LEWIS C. CHAPMAN.

A CHANCE OF MORE OIL IN SOUTHWESTERN TEXAS

The U. S. Geological Survey on July 24th issued a Press Notice with the above title describing anticlinal folding between Del Rio and Sycamore Creek, in Val Verde County, Texas. The structure is an anticline with its axis extending west by north, crossing Sycamore Creek about 2 miles south of the Southern Pacific Railway near Johnstone siding, and extending across San Felipe Creek 3 or 4 miles north of Del Rio. The abnormal eastward extension of the Buda limestone, almost surrounded by the Eagle Ford formation, afforded the clue to the recognition of the structure. This evidence was checked against the War Department topographic map (not published) and the formation boundaries plotted on cross sections made from that map show a reversal of dip of about 100 feet within a distance of about 4 miles north of Johnstone. Since the notice was written the Reclamation well in sec. 491, Bl. 4, 6 miles north of Del Rio, found asphalt in the basal Cretaceous sand at a depth of about 2,500 feet. Seepage oil now produced

at San Felipe Springs near Del Rio issues from a fault zone in the Georgetown limestone. In this connection it is interesting to note that in 1907, J. A. Udden¹ mentioned the reported occurrence of oil in "some well Johnstone Siding."

¹Report on a geological survey of the lands belonging to the New York and Texas Land Company, Ltd., in the Upper Rio Grande embayment in Texas. Augustana Library Publications No. 6, Rock Island, Ill., p. 66, 1907.

L. W. STEPHENSON.

ORDOVICIAN OIL AT HEALDTON

A third well in the Healdton oil field has been completed in the Ordovician. It is the Gilmer Oil Co. Hernstadt No. 5, NE cor. NW¼, SE¼, sec. 4, T. 4 S., R. 3 W., depth 2,100-2,200 feet. The oil is 42 gravity and is similar to that found several years ago, but the depth is shallower.

SIDNEY POWERS

DISCUSSION

Wildcat Wells in South-Central Arkansas Stop Short of Deep Oil Sands.

U. S. G. S. Press Notice, April 22nd, 1921, 8 pages and
correlated graphic logs, This Bulletin, Vol. 6, p. 350.

This press notice of the U. S. Geological Survey is a warning that more oil and gas production in South-Central Arkansas is not being discovered because of too shallow drilling and careless rotary methods.

These two causes of unnumbered failures have long been recognized by operators and geologists, who have often been helpless before the gods of Expense and Speed. Deep holes are costly and frequently dry even if scientific, and core barrelling takes time and prevents the driller from making hole. Furthermore, new pools have been discovered in such rapid succession in North Louisiana and South Arkansas, that one district has not begun to be thoroughly developed before a new one demanded the operators' attention.

In the last year, however, new production from greater depths, both actual, structural, and stratigraphic, has shown the importance of going deeper. Production was found at Haynesville, Louisiana, in the Blossom sand deeper than before known,—700 feet both structurally and actually lower than the Blossom at Homer. Likewise, it was found at El Dorado, Arkansas, in the Nacatoch, 700 feet lower than the same sand at Homer. Furthermore, a new producing horizon was found at Pine Island in the Caddo, Louisiana, field for the first time in the Glenrose formation of the Trinity series at a depth of 2,900 feet below the surface.

Phenomenal production from these unprecedented depths in this territory gives weight to the advice of the Survey that, "Cores should be cut from all beds penetrated that yield showings and particularly from a sand in the Nacatoch, Marlbrook, Brownstown, Blossom, Eagle Ford, Woodbine, and Trinity formations, whether or not oil showings are observed in the sludge."

A large part of the paper is taken up with a description of the formations encountered by drillers in Union County, Arkansas. This is the results of a detailed study of many well records by W. W. Rubey, and together with a typical log of the El Dorado field forms a valuable guide for wildcaters.

The general structure of the region, including regional southeast dip and thickening of beds toward the center of the Mississippi Embayment, is graphically shown by cross section correlation of eight well logs from Howard County to Union County. This indicates a slight flattening or terracing of dip near Stephens and El Dorado.

A few points brought out in the paper whose truth may not be generally realized are:

1. "The principal oil sands of the Caddo and De Soto-Red River

districts in Louisiana (which are commonly but erroneously called the Woodbine sand) are probably of Eagle Ford age."

2. The Eagle Ford formation contains red shale which may be used for correlation purposes.

3. The Annona tongue of the Austin chalk may be absent in South-Central Arkansas, although it probably is not always recognized because of its shaly nature.

4. The Woodbine sand, so far as known, has not been reached in Union County. Quoting L. W. Stephenson, the paper suggests that Woodbine may be represented by an unconformity.

5. The Trinity formation is probably 4,000 to 5,000 feet below the surface in this region.

It is correctly stated that many wells in South-Central Arkansas stop short of the Nacatoch and the Blossom sands. It is likewise stated that in other fields several sands below the Nacatoch have been more productive than the Nacatoch, and in fact the Nacatoch has been barren in some fields.

It is stated, however, that the sand in South Arkansas corresponding to the producing Eagle Ford (erroneously called Woodbine) in De Soto-Red River, probably lies 1,300 to 1,400 feet below the top of the Nacatoch, or at a depth of 3,400 to 3,500 feet below the surface. In April, when the Press Notice was written, few if any wells in South Arkansas had been drilled that depth, and this fact apparently furnished part of the reason for the title, "Wildcat wells in South-Central Arkansas Stop Short of Deep Oil Sands," but the necessity of drilling that deep is not at all clear.

If we agree, as some geologists do, that the Woodbine is absent at El Dorado and in the De Soto-Red River field, and that production in the latter place comes from the Eagle Ford, and if we agree, as a number of geologists who have studied the El Dorado field do not, that the Cooper-Henderson deep test at El Dorado is in Eagle Ford at 3,005 feet, then we should agree that the wells, at least those wells used in the correlation table of the Press Notice, went deep enough to reach the producing sand of the Eagle Ford, if there were such, and that it is unnecessary to go 1,300 or 1,400 feet below the top of the Nacatoch in Union County, for the following reasons:

1. In De Soto-Red River, the producing horizon is less than 100 feet below the first red shales and clays of the Eagle Ford.

2. The wells used in the correlation tables show depths several hundred feet below the red shale.

According to this argument then, it appears that the title of the Press Notice is appropriate for wells shallower than the Nacatoch and Blossom, but misleading as applied to wells in red shales of the Eagle Ford,—unless the operator wants to take the chance of drilling to the Trinity which is estimated by the Survey "to lie 4,000 to 5,000 feet below the surface."

J. P. D. HULL.

El Dorado Oil Field in Arkansas Not on an Anticline

U. S. G. S. Press Notice, May 15th, 1922, 6 pages and map, This Bulletin, Vol. 6, p. 358.

This press notice is the result of field studies of the geologic structure made in the summer of 1921 by W. W. Rubey, L. G. Mosburg, and H. W. Hoots, and office studies by K. C. Heald and W. W. Rubey.

This notice states, "The primary purpose of these studies was to learn the conditions under which oil is most likely to occur in southern Arkansas." It deals with the discovery and development, structure, source of oil and formation of pool, oil and gas above "pay" sand, possible extensions, suggestions for finding similar fields, description of producing bed, methods of constructing map, and character of oil.

The principal facts brought out by this study are the lack of pronounced anticlinal structure and the close association of gas, oil, and salt water in the same producing bed.

The striking feature of the geologic structure map is the portrayal of a number of small faults approximately parallel in a northeast direction. A quotation from the paper indicates their significance.

"The direction and arrangement of the faults, and the shapes of the folds that accompany some of them, probably indicate the presence of a large fault or zone of faulting in the beds deep below the Nacatoch Sand, trending about N 15° W. The structure shown by the oil sand there must have been produced by lateral movement along this fault, the strata east of it moving northward relative to the strata west of it."

The construction of this sentence is not clear, but apparently the authors accept the theory of A. E. Fath that a series of parallel faults are the result of torsional movement along a deeper fault zone with a trend at right angles to the shallower faults. Further, the authors evidently do not accept the evidence of faulting shown in the surface outcrops in the cen. SE¼ sec. 32 where a fault trends northwest, apparently bounding production on that side. Other geologists have failed to find subsurface faults in the field.

The authors believe the source of the oil is the Marlbrook marl about 400 feet below the producing Nacatoch sand. In fact, since the publication of the press notice, a few wells drilled 400 feet below the Nacatoch have found a little oil, several million cubic feet of gas, and much salt water. They also believe production from deeper sands cannot be counted on because El Dorado has neither pronounced regional uplift nor strong anticlinal folding, which are favorable features in the other deep-producing fields of southern Arkansas and northern Louisiana. It may be mentioned, however, as an encouraging comparison, that at Haynesville, Louisiana, production comes from the Blossom sand 2,800 feet deep, and 800 feet below the Nacatoch on a relatively low fold whose closure is only 60 feet. At El Dorado, there are probably closures of 30 feet and the total producing structural relief is as much as 70 feet.

Several suggestions brought out in the paper are (1) the importance of stopping the drill at the very top of the producing bed, since, "so far as salt water is concerned this field may be said to be all 'edge', and each well is a problem in itself." (2) the possibility of production in both shallower and deeper sands, and (3) the probability of nearby fields of similar character.

Two sentences that stand out from others in the reader's mind are here mentioned: (1) "The great number of test wells that have been drilled in southern Arkansas without finding oil in large quantity except in the El Dorado field show either that the oil pools in this region do not bear the same relations to anticlinal structure that they commonly bear elsewhere in the Mid-Continent Oil fields, or that geologists have not learned how to locate the anticlines in this field by studying the surface conditions." This statement, made with the apparent premise that all southern Arkansas test wells have been located by geologists and drilled with geological precaution, is very flattering to stock concerns, contract drillers, and wiggle-stick artists. (2) "The records of wells drilled with rotary tools are notoriously poor and afford very unreliable correlations." This is the truth, but not all of it. There are drillers and then again there are drillers. To cite Haynesville once more—geology found it and drilling almost lost it.

J. P. D. HULL.

Shreveport, La., July 5, 1922.

REVIEWS AND NEW PUBLICATIONS

Unproved Areas. By LAWRENCE VANDER LECK, California

State Mining Bureau, Bull. 89, 1921.

California State Mining Bureau, Bull. 89, 1921

This recent publication by the California State Mining Bureau has supplied a long-desired need for a summary statement of the petroleum possibilities of the State. It is sincerely hoped that Mr. Vander Leck's clear map and pointed statements as to the situations existing in all parts of California will have an effect on diminishing the large sums of money spent on drilling in areas where obviously there is no chance of obtaining oil. The book should be consulted by every prospective investor before placing his money with a "wildcat" company. As Mr. Fletcher Hamilton, State Mineralogist, has so concisely stated in his letter of transmittal to the Governor of California. "The increasing demand for petroleum and its products, and the inability of production to keep pace with requirements, for several years, have resulted in widespread prospecting throughout the world for possible new oil fields. In California, 'wildcat' wells are being drilled in many localities, some of them in places where even a cursory inspection of the geology would tell of the futility of looking for oil. For this reason, the report herein aims to furnish information as to the unfavorable as well as to the favorable areas for development of additional petroleum resources in California."

After a "General summary of conclusions" which is well-placed at the beginning of the book, Chapter 1 discusses the "General theory of the origin and accumulation of oil in California." In trying to make this comprehensive subject as concise as possible, the author has left out many essential points. His definition of the organic theory is extremely vague. Diatoms and forams are taken for granted as the source for the oil in California—diatoms for the reason that the "California oil shale shows that they (samples) vary from 65 per cent to 85 per cent silica." It is extremely doubtful whether forams could act as a source for oil¹. Three theories are given for the migration and accumulation of oil, namely, (1) anticlinal, (2) moving waters, and (3) the diastrophic theory of Marcel Daley. These are very briefly explained with the conclusion that "It is very probable that all of the above theories contain some element of truth, and the forces that contributed to the migration may possibly be a combination of all these forces." This part could be greatly improved by the addition of references to the literature on the various theories. A summary statement is given of the structures in which oil occurs in California, all of which bear out the rather positive assumption that "oil travels later-

¹Personal communication from Dr. Albert Mann of the Smithsonian Institution.

ally and vertically—never downward.....” The discussion of the less theoretical part on “Reservoirs” presents a good idea of the underground storage condition in California, though the statement that “In general, fine-grained sands contain light oil, while coarse sands contain the heavy viscous oil” may be questioned. The part on “Saturation and recovery” is briefly handled, but adequately for this type of book. It mainly concerns the value of the gas associated with the oil. The different classes of “Surface indications of oil” found in California are given and their importance in relation to the occurrence of oil is pointed out.

Chapter 2 describes the oil-bearing formations of California. The State is divided into five provinces, and the general geology and structure of each province is briefly discussed. The oil-bearing formations, of California ranging in age from the Cretaceous to upper Pliocene, are dealt with in more detail. In the introductory paragraph the statement that “all known occurrences of oil in California are found in close formation with beds of organic shale” is misleading. Although some of the organic shales closely associated with the occurrence of oil in California contain diatoms and may, in places, be composed almost entirely of them, still a very large part of the oil shales contain very few, if any diatoms. For example, the oil derived from the Eocene in Ventura County is certainly not associated with diatomaceous shales. Short descriptions of the California oil-bearing formations are difficult to give when it is considered that the lithology varies so greatly from place to place. As a whole, Mr. Vander Leck has handled the subject well, listing the principle localities where the formations occur, and stating the mode of occurrence of the oil in them, the kind of oil, and the commercial possibilities of the formation. As regards nomenclature, always a vexatious task in California stratigraphy, he has, in general, followed that used by Dr. B. L. Clark of the University of California.

The remainder of the book is taken up with the detailed discussion of the prospects for oil in California. For this purpose, the State has been divided into eleven districts with a chapter devoted to each district. The geology of the areas is briefly summarized and where certain districts are oil bearing or offer possibilities for oil, details of the geology are given either from first hand information of the author, or from quotations and abstracts of other geologists' work, supplemented by the author's own observations. Where the geology has been taken from old Government and State reports, it is not always accurate in the light of our present knowledge. A great deal of valuable data is given on the results of the wildcat wells of the districts, information about which is sometimes difficult to get years after the wells have been drilled. A colored map has been included showing the proven, possible, improbable, and impossible areas of the State. Though references are freely given, a welcome addition would have been a more

complete bibliography of the literature relating to the petroleum geology and industry of California. Numerous grammatical errors, involved and abstruse sentences, and misspelled words show that the book could have been markedly improved by editing.

As a whole, the author's conclusions are reliable, the data on the fields useful, concise, and well-arranged, so that the book should be of considerable value not only to the ordinary investor, but to anyone interested in the petroleum industry of California.

W. S. W. KEW.

Appraisal of Oil Production By J. H. HIGHSMITH, published by the author, Lawrenceville, Ill., 1922. pp. 132, price \$5.00.

The chief contribution of this book is a series of tables for use in determining monthly depletion rates based on past performance of oil-producing properties, and for estimates of future yields.

The book opens with a two-page introduction on the subject of oil appraisal by R. S. Blatchley, in which he compares three methods of estimating oil reserves, (1) production curve method, (2) porosity method, (3) direct percentage method.

The reviewer wonders if Mr. Blatchley is as prejudiced against the production curve method as his comments imply. This method is graphic and hence may appear less accurate than the direct percentage method, but in the hands of anyone with some experience and appreciation of oil production, it gives good results and obviates one inaccuracy of the latter method, the assumption of a fixed rate of decline. Certainly it is no more, but is rather less arbitrary than the direct percentage method which assumes a fixed rate of decline, such as may be approached by a property in old age but which, so far as the reviewer knows, is never actually reached. The older the production the less rapidly in general, does the decline rate change. In the case of old properties tables should give reasonably accurate results, but consistently should run low.

Mr. Highsmith takes up the problem of estimating future reserves, and includes examples with solutions which are intended to illustrate the use and scope of the tables in the book. Each table consists of four columns, (1) a time column of one to twelve months followed by year totals through ten years, (2) a given monthly depletion rate applied each month for the same time interval as that in column one, (3) the residual or "depletion point" as it is called by the author for each of the time intervals given in column one, and (4) a factor which represents the cumulative or total production through each of the time intervals. The tables are based on a monthly decline rate, which is assumed to remain constant in the future. The range of these rates is from $\frac{1}{4}$ per cent per month up to 3 per cent by $\frac{1}{16}$ per cent intervals, 3 per cent to 5 per cent by $\frac{1}{8}$ per cent intervals, and 5 per cent to 10 per cent by $\frac{1}{4}$ per cent intervals.

While it is not possible precisely to estimate future oil reserves, aid to accuracy and speed in such work are valuable, though greater convenience and ease of use do not necessarily mean greater accuracy.

Mr. Highsmith explains the use of the tables in a simple and concise manner. The last paragraph on page 9, to the effect that "it is evident in most cases that the later life of a well or property affords a safer basis for calculation by any method," is worthy of emphasis, and he might have added, "no method yet devised is fool-proof."

One point to which attention should be directed is the fact that these tables are intended for use in the study of individual wells or leases where no drilling has taken place during the period for which the average rate of decline is determined, nor is any allowed for in the future. If these limitations are not adhered to, the results attained lose accuracy.

Mr. Highsmith has chosen examples which show in an admirable manner the convenience and utility of such tables. His solutions are clearly given, and should be followed by anyone without difficulty. A statement of problems which are presented will indicate some of the occasions where the booklet can be of considerable assistance.

Problem 1. Find the monthly production and total yield, at the end of three years, of a property producing 3,000 bbls. monthly on which the monthly decline rate is shown to be $1\frac{1}{4}\%$.

Problem 2. Same condition as No. 1. Time 3 years, 7 months.

Problem 3. What monthly decline rate is indicated by a decline in the monthly production from 3,000 bbls. to 1,285 bbls. in 4 years?

Problem 4. What monthly decline rate is indicated for a property with a basic monthly production of 9,875 bbls., which showing a steady decline, yields 275,250 bbls. in 3 years?

Problem 5. What monthly rate is indicated by a drop in the monthly yield from 3,875 bbls. to 2,925 bbls. in 2 years and 8 months?

Problem 6. What monthly decline rate is indicated for a property producing 3,275 bbls. monthly which, showing a steady decline, yields 76,425 bbls. in 3 years and 6 months?

Problem 7. A property with an average monthly production of 4,875 bbls. on January 1, 1918, showing a steady decline yielded to January 1, 1921, a total of 141,785 bbls. The monthly operating cost being \$1,575.00, place a valuation on the production on a 7% interest paying basis only, with market price of oil running throughout at \$1.75 per bbl.

Problem 8. A property showing a daily average production of 125 bbls. and a depletion rate of $\frac{3}{4}\%$ monthly is purchased for \$1,600.00 per bbl. The monthly operating expense being \$1,500.00, in what time will the property pay out, allowing 7% interest, with the price of oil running throughout at \$1.75 per bbl.?

The reviewer cannot agree with the author in his solutions for the problems 7 and 8.

The author calls attention to the fact that his "solution does not take into account the reduction of the interest charges by the amount of interest earned after the first year on returns from the sale of production." A serious error which is involved in the solution is the method used for determining the net value of oil per barrel for each year's run. This has been determined on the basis of the first year's production, although the monthly operating cost is essentially a constant, the monthly yield is a declining amount, and the cost per bbl. is therefore a variable, increasing towards the end of production. Such a calculation shows a net value of

\$1.25 per bbl. for the first year's production, and this net value is applied to all subsequent production, obviously an oversight on the author's part.

The author's results for this problem are as follows: During a period of 8 years and 9 months the property should yield 188,591 bbls. which at 7% interest should have a present value of \$146,194.57, and the value per bbl. on the basis of the January 1921 production (105) would be \$1,392.00. The reviewer has recomputed this problem on the basis that an investor would expect 10% interest on his investment for the life of profitable production, that the proceeds for each year's oil sales might be considered as coming in during the middle of that year, and that the replacement or amortizing fund should build up at 4% compound interest. On such a basis, this property would have a profitable life of 6 years, during which time the total yield would be about 152,220 bbls. The net receipts for each year's production would be as follows: \$42,768.25, \$34,532.75, \$27,396.25, \$21,213.50, \$15,756.75, and \$11,214.00. These amounts capitalized as above outlined would have a present value of \$104,550.84, and the value per bbl., based on the January 1921 production would be about \$1,000.00. As such a method of capitalizing future income is commonly applied to the valuation of a mining property, the reviewer considers it as applicable here.

Mr. Highsmith in his solution for problem 8, finds that at the end of the fifth year the property will have overpaid by \$2,955.00, and should have produced 180,366 bbls. Here again the reviewer starts out on a different premise. He considers that 10% interest is the minimum an investor should expect on such an investment, and allows the amortizing fund to compound at 4% interest. On such a basis, this property is worth only \$184,454.00 (or about \$1,475.00 per bbl.) and would take 8 years to pay out. The yield during this period would total about 253,435 bbls. In this case the amounts which are capitalized are as follows: \$56,452.00, \$50,013.75, \$44,146.00, \$38,777.28, \$33,879.94, \$29,392.13, \$26,298.50, and \$21,558.46.

With the limitations in mind to which attention has already been directed, the reviewer can cordially commend this booklet to the attention of all those who are concerned with the valuation of productive oil properties, and he believes that it is a real addition to our literature on petroleum problems.

JAMES H. HANCE.

Oil Finding, By E. H. CUNNINGHAM CRAIG, published by Edward Arnold. London, 1920.

The second edition of this valuable book is an enlargement and amplification of the first that was published about 1912. The work consists of some three hundred odd pages and deals with the theories of the origin and occurrence of petroleum. It covers in a thorough way the field of petroleum geology. Also, there are chapters on related subjects as, "Petroleum Prospects in Britain" and "Field and Office Methods."

The volume is a contribution to science, and treats the subject of petroleum geology in perhaps the most orderly, concise, and thorough manner of any book that has, as yet, been published. In addition, it is a most welcome departure from the ancient and established custom of quoting Peckam, Newberry, and Orton as oracles, and, after this preliminary step, proceeding to compile a digest of what everybody else believes except one's self. A man, widely traveled, and keenly observant, Craig has given the profession the benefit of his studies undi-

luted by numerous quotations from the writings of others. The work is distinctly that of a field man and not of a librarian. Even though many of us may differ with him in some of his conclusions, the reviewer believes, his book stands as the best published contribution of the statement of the science of petroleum geology as it is known today.

Chapter I, devoted to "The Origin of Petroleum" covers forty-three pages. Six pages are given to examples disproving the volcanic theory. These examples are very interesting especially the description of cracked oils that occur in the dolerite dikes of South Africa. The next twenty-two pages are devoted to statements of the theories of animal origin and an attempt to disprove them. The theory of vegetable origin is then considered for seventeen pages and the chapter terminated with a discussion of the untenability of the suggestion that petroleum could have been formed from marine vegetation. The whole chapter is really an attempt to prove the origin of oil from terrestrial vegetation accumulated under deltaic conditions.

Chapter II, entitled "Process of Formation" refers entirely to the supposititious formation of petroleum from terrestrial vegetation. Various suggestions are offered and field examples quoted in support of the argument which is carried on under the sub-titles of "Pressure," "Temperature," "Salt and Brine."

Chapter III is headed "The Migration, Filtration, and Subterranean Storage of Petroleum." The first few pages are taken up with a discussion of petroleum as a colloidal solution. Then statements are made against the acceptance of the idea of the migration of oil over wide areas as a general phenomenon. The author considers migration a special or local condition. The various subjects of "Hydrostatic Pressure," "Gas Pressure," "Surface Tension," "Filtration," "Subterranean Storage," "Contour of Grain," and "Porosity" are treated under these sub-titles. Filtration effects are treated at considerable length and seem to be given unusual prominence. Under surface tension a "crack" is taken at our prevalent use of the term capillarity, and two quotations are given. The quoted discussions of capillarity are so badly jumbled and confused that they have little meaning. The author gives them as verbatim from what he alleges are, "recently published books upon petroleum . . . hailing from the United States." It is then explained in a kindly manner that capillary attraction is an obsolete term and that the correct and proper phraseology is surface tension.

Chapter IV is entitled "Lateral Variation." The change in character of sediments that compose a horizon or are laid down during any period of deposition are discussed at length with examples taken mainly from Trinidad and Burma.

Chapter V is devoted to a discussion of geological structures and numerous examples of the working out of such structures given for various countries.

Chapter VI is on "Indications of Petroleum." These are listed as: (a) seepages of oil, (b) asphalt deposits, (c) evolution of gas from

strata, and (e) veins of manjak or ozokerite. Evolution of hydrogen and crystals of sulphur are appended. Attention is called to the fact that petroleum seepages nearly always represent either oxidized or filtered oils. There is also a rather full description of the pitch lake in Trinidad, and numerous localities are listed where this type of manifestation occurs. The chapter is closed with a tabulated list of what the author considers favorable and unfavorable indications.

gas-pools, mud-volcanoes, or dry ground, (d) outcrops of bituminous

Chapter VII has the title, "Natural Gas or Gaseous Petroleum." The term "gaseous petroleum" coined by Sir Boverton Redwood is used by the author in preference to what he calls the American misnomer of "natural gas." The chapter treats fully the geological occurrence of natural gas at a number of localities.

Chapter VIII on oil-shales and torbanites devotes the first half to a theoretical discussion of the origin of Scottish oil-shale while the latter part carries out the same idea for torbanites, that is, cannel coal.

Chapter IX is on Stratigraphy. This arrangement may seem peculiar to those accustomed to see the subject treated at the beginning of most books or reports. One interesting subject in the chapter is a description of the method used by the Burman Oil Co's geological staff in zoning their fossils. The author mentions that most satisfactory results were obtained in separating the series into mappable units without any of the members being trained paleontologists.

Chapter X on the location of wells discusses the various methods used in following a "hunch," and the possibilities of electrical divining rods. The author seems to give more credence, than most of us to the possibility of an electrical instrument that will measure relative conductivities of oil or water impregnated sub-surface strata. The major part of the chapter deals with the location of wells on asymmetrical anticlines. Locations on other types of structure are considered in less detail.

Chapter XI is on the "Petroleum Prospects in Britain." The author summarizes the prospects of that country and concludes while structure, stratigraphy, and indications of petroleum are favorable that any such deposits have been dissipated, that possibility of commercial oil is very doubtful, and that was justified only as a war measure.

Chapter XII which is on "Field Work (for beginners)" contains many useful hints from the author's wide and varied experience. Most of the methods cited are especially applicable to unknown country as is found in the tropics. The widely used plane-table, that is more or less the basis of all American practice, is not touched. With some of the methods recommended and the conclusions drawn probably many American geologists will take issue. A case in point where the reviewer thinks the author decidedly in error is with the sketching board. He quite agrees that the old cavalry sketching board is of little use, but calls attention to the modified forms that are now manufactured which give excellent results. Also, horseback traversing is not to be despised

except for the most detailed work and then a plane-table and alidade is recommended.

Chapter XIII which closes the book is given to "Indoor Work" likewise "for beginners." This chapter contains many valuable hints, but the American geologist will probably find the author's procedure somewhat different from his own.

K. D. WHITE.

MANUSCRIPT BIBLIOGRAPHIES

The National Research Council has recently issued a "List of manuscript bibliographies in geology and geography." Under the heading Petroleum there are five entries. G. B. Richardson, U. S. Geological Survey, has several thousand entries of publications since 1900. E. W. Shaw has 1,000 entries, 90% complete, on Latin American petroleum. The Bureau of Mines issues monthly manuscript bibliographies of petroleum in mimeographed form. E. DeGolyer has 9,000 to 10,000 entries in petroleum and natural gas, 80% complete. Roswell Johnson has 7,000 entries of the same nature. These bibliographies may be consulted by all interested.

SIDNEY POWERS

NEW PUBLICATIONS

The branch office of the U. S. Bureau of Mines at 508 Consolidated Royalty Bldg. Casper, Wyoming, has issued the following publications:

Report of Operations of the Rocky Mountain Petroleum Association; May 16, 1919 to May 15, 1921, by F. B. Tough, et al. The cost is \$1.00.

Circular No. 5 (2 Mimeographed pages) deals with the computation of government royalty.

THE ASSOCIATION ROUND TABLE

COMMITTEE WORK

Many activities of organizations whose membership is geographically widely scattered, are necessarily performed through the instrumentality of committees. It is commonly the fate of these committees to struggle along unaided, with the work allotted to them, until such time as they are to submit their report and disband. It is unfortunately true that the average member of most scientific societies usually totally ignores the work of committees while it is in progress, and then exercises the utmost freedom in criticising the report when submitted. Attention is once more called to the work of an important committee of the Association, in the hope that members will be aroused out of their lethargy to offer support and suggestions.

The Constitutional Committee has before it the task of recommending to the Association a new method of electing officers. For some time there has been a feeling that the present method of conducting elections is not entirely satisfactory. It has been contended that a larger number of nominations should be submitted for the several elective offices and there has been criticism of the fact that members unable to attend business meetings were denied a vote in the elections. It has been pointed out that on several occasions officers were elected by a majority vote of those in attendance at the meetings, though the entire vote cast represented scarcely more than one-quarter of the total membership.

If absentee voting is to be provided for, the balloting must be conducted through the mail and if announcement is to be made at the annual meeting of the selection of officers for the ensuing year, some means must be found for making nominations well in advance of the meeting. There is a marked indisposition among members to reduce the election of officers to a stereotyped process. Those who support the present system do so largely because they believe the "convention system" adds an active interest to the meetings and encourages attendance. Though the system has worked satisfactorily in the past, it will scarcely be denied that it makes possible electioneering and pledging of votes, which may serve to arouse personal animosity and thus interfere with the successful functioning of the Association as a scientific body.

It will be seen that there are several difficult angles to this problem. Judging from the active discussion of this topic at meetings, the Constitution Committee was justified in expecting hearty assistance from the membership, but despite the fact that the committee has been in existence for over half the current year, only two or three suggestions of a constructive nature have thus far been received. It is hoped that anyone with suggestions which are likely to prove helpful in formulating a workable election plan will not delay longer in communicating them to the Chairman, Chester W. Washburne, 2 Rector Street, New

York, or to other members of the committee, F. G. Clapp, W. E. Pratt, and Jas. H. Gardner.

W. E. WRATHER.

MEMBERSHIP APPLICATIONS

During past years it has been the duty of the Executive Committee to pass upon the qualifications of applicants for membership in the Association. It is now the custom for some member of the Committee, usually the Secretary, to supplement the data contained in the original applications, with information from other sources, if such data are incomplete or inadequate; and upon the unanimous approval by members of the committee, the applicant is declared elected.

During the past two years there has been a great increase in membership, and many applications have been received from widely scattered localities. It has been increasingly difficult for the Executive Committee to secure adequate information upon which to elect members, since it is frequently desirable to know more about the qualifications of applicants than is supplied in the usual manner. It was accordingly thought advisable to publish in the Bulletin a list of pending applications, together with the names of the sponsors, and defer election until after a sufficient lapse of time for members to communicate to the Secretary any data which might have a bearing on the final action of the Committee. The standards of membership can best be maintained if members will co-operate with the Executive Committee by promptly checking over the lists appearing in the Bulletin and furnishing pertinent data to the Secretary.

W. E. WRATHER.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This publication does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to Charles E. Decker, Norman, Oklahoma.

(Names of sponsors are placed beneath the names of each applicant.)

FOR FULL MEMBERSHIP:

Robert M. Overbeck, Long Beach, Calif.

R. E. Collom

Wm. S. W. Kew

E. F. Davis

Wilfrid H. Geis, Casper, Wyoming.

Max W. Ball

Carroll H. Wegemann

Harold T. Morley

- Orion H. Eichelberger, Houston, Tex.
Donald C. Barton
Wallace E. Pratt
E. De Golyer
- Bruce Wade, Tampico, Tamps., Mexico.
R. Leibensperger
W. A. Ver Wiebe
D. R. Semmes
- Harry E. Crum, Paola, Kansas.
C. A. Fisher
W. H. Twenhofel
C. E. Decker
- John C. Myers, Greeley, Colo.
E. L. Jones, Jr.
J. M. Armstrong
Glenn C. Clark
- Clarence E. Hyde, Oklahoma City, Okla.
Irving Perrine
W. C. Kite
L. E. Trout
- Charles M. Rath, Denver, Colo.
Carroll H. Wegemann
Clarence B. Osborne
Max W. Ball
- William J. Wright, Shillong, Assam, India.
J. E. Hawley
D. Dale Condit
Max W. Ball

FOR ASSOCIATE MEMBERSHIP:

- R. C. Cash, Houston, Texas.
Wallace E. Pratt
D'Arcy M. Cashin
Chas. E. Decker
- Ionel I. Gardescu, Pittsburgh, Pa.
L. G. Huntley
Paul Ruedemann
R. E. Somers
- Robert B. Campbell, Shreveport, La.
Eugene Holman
Wallace E. Pratt
D'Arcy M. Cashin
- Robert R. Osborne, Pittsburgh, Pa.
L. G. Huntley
Paul Ruedemann
R. E. Somers

Shamus O'Brien, Florence, Kansas.

R. S. Knappen

A. C. Gester

R. C. Moore

Sam Kornfeld, Tulsa, Okla. .

James H. Garden

W. B. Wilson

Harry H. Nowlan

AT HOME AND ABROAD

H. A. NOBLE, of Tampico, has visited the Laredo, Texas, district.

HARVE LOOMIS is representing N. L. Amster, with headquarters in Tulsa.

The Bend arch in Texas was first recognized in 1915 by Dr. E. T. DUMBLE in the Trans. Amer. Inst. Min. Engrs., Vol. 52, p. 250, where he refers to it as the Lampasas geanticlinal and states that the uplift occurred after the deposition of the Bend series and extended from the old Paleozoic land area of the Llano region toward Red River.

HENRY HOWE has been appointed professor of geology at Louisiana State University.

EUGENE HOLMAN, of Shreveport, spent his vacation in California.

E. T. DUMBLE, of Houston, has purchased an estate at Tunstall, Virginia, near Richmond, and will spend the major portion of his time there and in New York.

W. H. FOSTER, of Tulsa, has been in Mexico City.

J. Q. MYERS, of Tulsa, spent September in Wyoming and Montana.

C. R. THOMAS and W. C. KINKEL, of Tulsa, took a trip through Wyoming and Montana in September.

W. L. WALKER is now living on a ranch near Bakersfield, California.

HARRY BROWN and W. L. LONGMIRE, of the Pierce Oil Corp., will have headquarters in Tulsa.

K. C. HEALD, of the U. S. Geological Survey, has been making a tour of the West. Recently he has been making a survey of the Ingomar dome in Montana.

DONALD MACDONALD has been presented by the United States with a testimonial for his work on the Canal Zone.

RAYMOND LEIBENSBERGER, of the Transcontinental Oil Co., of Mexico, published a paper on the history of oil development in Mexico in the Lamp for October.

W. W. RUBEY of the U. S. Geological Survey has accepted an appointment as instructor in geology at Yale University, and begins his new work in October.

WALTER A. ENGLISH has recently joined the staff of the Standard Oil Company of California. One June 6th he was married to Miss Lucille Curtis in Los Angeles.

W. C. KITE, of Oklahoma City, spent the summer in Eastern Canada.

ELMER H. FINCH is in Central America where for some months he will be engaged in geological work. His address is Hotel Grace, Guatemala, C. A.

VERNON F. MARSTERS is now located in the Hayes Bldg., 920 Grand Ave., Kansas City, Mo.

LEON J. PEPPERBURG has opened a new office for consulting work in the American Exchange Bank Bldg., Dallas, Texas.

W. Z. MILLER discovered the Otoe structure for the Gypsy Oil Company.

L. G. HUNTLEY and STIRLING HUNTLEY have opened offices in the Frick Bldg., Pittsburgh, Pa., under the firm name Huntley & Huntley.

K. D. WHITE is in Argentina, S. A. His address is Seccion K, 5 Piso, 560 Avenida de Mayo, Buenos Aires.

FRED B. ELY is engaged in geological work in Europe with headquarters at 82 Avenue de Champs Elysees, Paris.

EDWIN B. HOPKINS has recently returned to New York from a trip to Venezuela and Trinidad.

R. A. CONKLING is Chief Geologist of the newly organized North American Oil Co. (C. F. Colcord) with headquarters in the Colcord Bldg., Oklahoma City.

F. K. FOSTER has resigned from the White Eagle Oil & Ref. Co. to do some special work at the University of Nebraska.

J. G. BARTRAM, of Ardmore, spent his vacation in Colorado.

A. M. MACKENZIE is Chief Geologist of the Mammoth Oil Co., with headquarters at the Teapot Dome camp.

F. B. TOUGH has succeeded A. W. AMBROSE as Chief Petroleum Technologist of the U. S. Bureau of Mines.

LUTHER WHITE is a Director of the newly organized J. A. Hull Oil Co. with headquarters in the Kennedy Bldg., Tulsa.

G. E. ANDERSON, who has been engaged in consulting geology at Fort Worth, will assist PROFESSOR J. B. UMPLEBY at the University of Oklahoma during the present year.

ALEXANDER DEUSSEN was the first geologist to recognize the Mexia fault and he stated in U. S. Geol. Surv., Water Supply Paper 335, 1914, p. 301 that "A fault of small throw crosses the country in a northeast-southwest direction. This fault has broken the continuity of some of the sand lenses that occur in the Navarro formation of the Cretaceous, and it is probable that the gas in the Mexia district is struck in these

discontinuous and locally warped sands on the east side of the fault."

PAUL RUEDEMANN is with COL. M. W. THOMPSON of New York City.

O. B. HOPKINS, Chief Geologist for the Imperial Oil Co. of Canada has returned to the United States, after several months in Peru inspecting the company's holding in Peru, and organizing geological work there.

T. O. BOSWORTH, former Chief Geologist for the Imperial Oil Company, is visiting American oil fields in the interests of a newly organized English oil company.

The Oil and Gas Section of the U. S. Geological Survey now has a permanent representative in the California fields. MR. W. S. W. KEW's headquarters have been transferred to Los Angeles from Washington.

J. E. BRANTLEY, Geologist for the Atlantic Refining Company, has returned from Mexico and is temporarily located at Shreveport, La., in charge of geological work for the Atlantic Oil Producing Company in Louisiana and Arkansas.

F. J. MILLER is in charge of the geological office of the Texas Company recently reopened at Shreveport, La.

J. B. KERR, formerly with the U. S. Bureau of Mines and co-author with H. W. BELL of a report published by the State of Arkansas on the El Dorado, Arkansas, Oil and Gas Field, is now on the geological staff of the Standard Oil Company of Louisiana with headquarters at Shreveport, Louisiana.

F. X. BOSTICK is paleontologist for the Standard Oil Company of Louisiana with S. C. Stathers, chief geologist, at Shreveport, La.

C. M. BENNETT, vice-president of the Louisiana Oil Refining Corporation and W. C. SPOONER, chief geologist of the Arkansas Natural Gas Company, both of Shreveport, La., made an overland automobile trip in August to the Wyoming and Montana fields.

FRANK A. HERALD, of Tampico, spent his vacation in Tulsa.

A. F. MELCHER, of the U. S. Geological Survey, has devised a hollow bit to break off cores in cable tool drilling.

C. F. BOWEN, Chief Geologist of the Standard Oil Co. of New Jersey, is now in room 322, 26 Broadway, New York City.

J. W. BEEDE has resigned from the Bureau of Economic Geology, at Austin, Texas, to accept a position with the Empire Gas & Fuel Co. at Bartlesville, Okla.

E. W. AMES is engaged in consulting geology at 1302 F. & M. Bank Bldg., Fort Worth, Texas.

A. W. AMBROSE has been appointed Assistant Director of the U. S. Bureau of Mines.

CHARLES ROTH, of the Midwest Refining Co., is Acting Secretary of the Rocky Mountain Association of Petroleum Geologists at Denver.

W. I. ROBINSON reviews the oil and gas possibilities of Michigan in the National Petroleum News for Sept. 6, 1922, with a list of all wells in the state which are reported to have shown oil or gas.

A. B. ROWLEY described the geology of western South Dakota in the Oil Weekly for Sept. 9, 1922. R. A. WILSON described the oil and gas possibilities of the State in Bull. 10, South Dakota geological and Natural History Survey.

GEOLOGISTS working on the Tertiary in any country bordering the Pacific or in the West Indies will find convenient correlations in the proceedings of the First Pan-Pacific Scientific Conference, part 3, published by the B. P. Bishop Museum, Honolulu, 1921.

E. H. SELLARDS issued a press bulletin from the Bureau of Economic Geology about Aug. 25th, describing the geology of Caldwell county and the formations penetrated by the Rios well near Luling. The oil is believed to come from the Edwards limestone.

J. B. BLANCHARD is with the Gulf Production Co. at San Antonio, Texas.

R. D. GOODRICH is now in business for himself.

E. G. SINCLAIR, Divison Geologist for the Midwest Refining Co. at Casper, Woming, is making an investigation of the California oil fields.

J. Y. SNYDER discovered the new Arcadia, Louisiana, salt dome. The test of Smitherman et al. in sec. 29, T. 18 N., R. 5 W., encountered rock salt at 1,400 feet and a new test is being started in sec. 20.

S. C. STATHERS discovered the new Bashaway, Louisiana, salt dome in sec. 16, T. 17 N., R. 8 W. The Standard Oil Co., Reese-Jordan No. 1 found the top of the salt dome at 799 feet. The Arkadelphia clay is exposed at the surface.

PAUL B. WHITNEY is with the Inland Oil and Refining Co., at Denver.

C. E. DECKER spent a portion of the summer in Illinois.

A. I. LEVORSEN is in Minnesota.

CLIFTON W. CLARK spent the summer in the Ozarks.

M. J. HOPKINS is Consulting Geologist at Casper, Wyoming.

G. L. HARRINGTON and E. F. BURCHARD, formerly of the U. S. Geological Survey are in Argentina.

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Taft		Bristow	Bradford	West Virginia
	Kentucky	Cleveland	Butler	Cairo
Colorado	Winchester	Cushing	Clintonville	Charleston
Denver		Drumright	Franklin	Clarksburg
Florence	Louisiana	Duncan	Kane	Mannington
	Oil City	Garber	Oil City	Parkersburg
	Shreveport	Haskell	Washington	Slatersville
		Kaw		
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HARVARD UNIVERSITY
CAMBRIDGE, MASS.

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BULLETIN
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OF
PETROLEUM GEOLOGISTS

RAYMOND C. MOORE,
Editor

NOVEMBER-DECEMBER, 1922
LAWRENCE, KANSAS

SHAFFER OIL AND REFINING COMPANY

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VOLUME VI

NUMBER 6

BULLETIN
OF THE
AMERICAN ASSOCIATION
OF
PETROLEUM GEOLOGISTS

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CONTENTS

Problems in Oil Geology and Their Advancement Through Co-operative Research	509
By DAVID WHITE	
What the Oil Company Expects of the Geologist	516
By ROBERT S. ELLISON	
Geological Work in the Carpathians	523
By WINTHROP P. HAYNES	
Some Graphical Methods for Appraising Oil Wells	533
By PAUL RUEDEMANN	
EDITORIAL	
Studies in Petroleum Geology, RAYMOND C. MOORE	545
RESEARCH PROBLEMS	
Temperature of Fluids in Wells, F. H. LAHEE	547
GEOLOGICAL NOTES	
Geological Section in Western Kansas, CHARLES T. LUPTON	549
Oil Possibilities of South Dakota, W. T. THOM, Jr.	551
REVIEWS AND NEW PUBLICATIONS	
ElDorado, Arkansas, Oil and Gas Field, SIDNEY POWERS	554
ASSOCIATION ROUND TABLE	
The Denver Meeting, C. E. DECKER	557
Membership Applications	559

OBITUARY

ROLLIN D. SALISBURY, W. E. WRATHER	563
GUY HENRY COX, V. H. McNUTT	566

AT HOME AND ABROAD

Current News and Personal Items of the Profession	570
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MEMBERSHIP LIST	572
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PROBLEMS IN OIL GEOLOGY AND THEIR ADVANCE-
MENT THROUGH CO-OPERATIVE RESEARCH*

DAVID WHITE

Oil geology at its present stage is but the beginning of a new branch of our science. It has no tradition such as has the study of the origin and mode of occurrence of metals. It has practically no history. Its real development, its possibilities, and its records of achievement are essentially matters of futurity. We who call ourselves oil geologists know that most of what we today call oil geology is little more than the application of the methods of stratigraphy, with specialization in structural study, to the discovery of oil pools. We have combined the technique, including mapping methods, developed in later years by the coal geologist, with the accumulated observations of the relations of oil pools to stratigraphy and structure in regions where oil has been discovered by the wildcatter or more recently by the geologist, who has applied the same methods of deduction and analogy. The discovery of the anticlinal theory was observational rather than deductive, and even at the present moment this so-called theory is perhaps more exactly a condition of observed relations than a real theory, architected from component principles. In newer

*Published by permission of the Director of the U. S. Geological Survey.

times we are studying also the relations of pools and structure to the occurrence of rocks accepted as mother substance of petroleum, to reservoir sands, and to waters and their movements. This is leading us to the more intimate study of the mother rocks themselves, of the sands, and of the history of deposition, deformation and erosion of the stratigraphic elements. Gradually we find our paths of inquiry leading into the composition of the sediments, the waters, the organic substances, and all the changes and mutual relations and reactions of the component parts of the geological and chemical ensembles, their original states, their histories, and their changes and products in response to chemical laws and dynamic forces and influences. Each step forward reveals new ramification, new factors and products, and new complexities as well as subsidiary branches to every problem. We shall find new compounds, new products, new relations, new reactions in multitudes, and—most probably—new elements and new principles.

In the practical world of oil field explorations oil geology is today scoring a great success, and our heads are in danger of being turned at the applause accorded by the industry and the public. But this success is only relative—merely the difference between a very little present knowledge and a former state of ignorance. We are steadily gaining in the ability to find new oil pools, but we have an amazing amount yet to learn. I conceive that in the estimation of the student of oil geology fifty years from now, the “ancients” in our science, will take rank little higher than “rock-hounds.” If we are to live up to just expectations, we must make good. We must replace our present high sounding crudities and superficial smattering by a genuine understanding,—by the mastery of the principles of oil geology.

The necessities of civilization have driven the exploration for petroleum far beyond the present limits of research. There has not been time, there has not been the reflective leisure, the endowment, or even the favorable psychological atmosphere for those researches on which gradually to build up the geology of oil into a systematic science. The really great secrets of oil geology are yet to be revealed. Even the elementary or primary facts of the origin of petroleum, though prob-

ably divined in part already, remain to be unequivocally demonstrated.

Returning again to our oldest and most strongly established dogma, the anticlinal theory, witness that it is, in effect, still in the stage of debate as to its exact mode of application and operation. The geologist assumes, generally correctly to be sure, that if oil is present it will be found in anticline or dome or terrace, if one is present; and largely by analogies in the region or province, he may successfully predict the general area of the fold within which the oil is more likely to be found. But this oil is almost never distributed throughout the fold fully according to theory; too often it does not occur anywhere in that quadrant or section of the fold which, on present theory, would appear to most geologists as most favorable. Its pernicious vagary for occurring in flats or in synclines, or of absenting itself completely, is sometimes annoyingly in evidence and may not always be explained rightly on grounds of porosity. When we have made sufficient progress in understanding all the factors conditioning the origin and occurrence of oil we shall know not only why the oil so frequently is not present where it should be and why it does not symmetrically conform to present theory on many seemingly most excellent domes, but also why it is sometimes found under stratigraphic conditions now regarded as anomalous. At present we too frequently pass out guesses, instead of that certain knowledge that will make for greater economy and efficiency in oil field development.

Again we have learned that source rocks are important to look for in any new region; but we have not yet fully determined as to just what rocks are source rocks nor why, in so many cases, we have important pools in series that appear so nearly devoid of source rocks or that lie very far from deposits now recognized as the probable mother substances of the oil.

To illustrate the primitive state of our present knowledge I have used two most common problems of the practical field geologist. To illustrate briefly and in a fragmental way, a very small part of the work waiting to be done I will next outline some of the studies needed in a very restricted portion of the great field of oil geology, namely, oil shale. I leave to others

the more complete analysis of their problem, as well as the enumeration and classification of the studies required in other more important lines and fields.

The recent failures and waste in the attempts to utilize oil shale for the production of artificial petroleum in the United States are due in part—in fact to an unknown extent—to our lack of knowledge of the origin, composition, relations, and possible distillation products of the highly varied chemical and mechanical organic constituents of the different oil shales and bituminous rocks. We should know the sources, present chemical composition and constituent compounds of the different kinds of fossil organic debris and the colloidal or solid products included in the ground-mass. Paleontological identifications of the fossil debris and the study of the results of geological changes must be followed or inseparably accompanied by microchemical tests and determinations of a most difficult sort. These are necessary to a knowledge of what the rock is made of. Next, we must ascertain the relations of the different kinds of component debris, residues, and other substances, many of which are optically distinguishable under the microscope, to the behavior of the rock under increasing temperature and under varying conditions of distillation. We must contrive a method of watching the micro-sections in a still so that by direct observation, if possible, we may learn the successive temperatures at which the different kinds of debris or products break down and what are the compositions and characteristic qualities of their products. By this combination of chemical and physical observations we will learn what the components produce, and which components contribute certain products under certain conditions. The settlement of these questions should enable us to determine by microscopical examination and chemical tests approximately what will be the character of the distillates to be gotten from a given shale, the type of retort to be used, and the conditions of temperature, pressure, etc., to be sought. Nearly every type of oil shale differs in its paleontology, its component debris and products, and by their present state. Had these researches, combining the paleontological, the dynamically geological, the chemical, and physical studies been

begun several years ago, the present situation as to our prospective oil shale industry would have been vastly better to say the least. Great losses would have been avoided. Losses to come may also be avoided. The physical tests should include, among other things, a series of shearing pressure tests, with records of temperatures induced, aimed at the solution of the genesis of natural oil from oil shale by geodynamic and geochemical processes. The question of natural cracking of the hydrocarbons in the strata under geologic processes also demands experimental research.

Before we can most effectively attack the host of unsettled problems bound up in the geology of petroleum, we should make a survey of the questions involved and requiring solution. The problems, so far as they can now be distinguished (new problems will later appear and apparent relations will change), should be defined, classified, and oriented according to their relations to one another and the main questions. This done, we should proceed to examine our work actually in progress, our interests and our capacities. These steps are necessary to plan any systematic attack. Structural, depositional, chemical, dynamic, and paleontological researches must be laid out in architectural plan and development. We then may cooperate in team work for the inauguration of researches bearing upon the different problems, in effect pooling then may co-operate in team work for the inauguration of research, we may be able to assist others in investigations beyond our own means or capacities.

I conceive it an important part of the work of this Association, an opportunity amounting to a duty in fact, for the members to systematically set up and catalog the problems now in view, putting our house in order, so to speak, for work and taking account of stock of the materials and oil geology equipment now in hand. If we clearly and logically envisage the problems and the pieces of work in sight to be done, we shall almost certainly bend our minds unitedly to the accomplishment of this work, and our efforts will be more constructive, as well as along lines most needed. The problems, which now obstruct the better understanding of oil geology will secure more widespread, more systematic and more effective attention. Re-

search students, candidates for advanced degrees in geology, paleontology, chemistry and physics, will be attracted and find subject-matter for these investigations to be carried out with the helpful interest of geologists and companies alike. Researches in certain field will, for their direct economic value, be conducted in company laboratories, or better, under the auspices of co-operating companies, to the benefit of the country as well as the industry.

Team work will increase as such studies progress in logical order and in the necessary fields, and the search for and the development of new oil deposits will gradually be transferred to a new and far more successful basis, founded on scientific research and the discovery thereby of principles, absolutely essential and possibly of great magnitude, not yet discovered. Not only may we all contribute to strengthen the work of others now under way, but it is more than probable that, as the great value of the researches is seen by the oil companies, funds for research laboratories and foundations will very wisely and profitably be established to further these investigations and so the real knowledge of oil, its sources and laws of occurrence.

ALEXANDER DUESSEN and E. L. ESTABROOK expressed opinions to the effect that the U. S. Geological Survey could render greater assistance to the petroleum industry in carrying on stratigraphic studies than in structural mapping.

COLIN C. RAE: The Midcontinent members should not conclude that the work of the United States Geological Survey has not been of considerable economic importance in the development of the Rock Mountain Oil Fields. We all realize that geological reports are revised in large companies as well as the Geological Survey, and that many details are only recognized after several wells have been drilled.

A little history of Rocky Mountain District Oil Fields might illustrate the value of the work of the Survey. In 1908, the first real large production in Wyoming was discovered in the Firt Wall Creek Sand of Benton, Cretaceous age in the Salt Creek Field. Consequently, oil prospecting was concentrated upon the location of favorable structures in the Cretaceous. Fortunately, the United States Geological Survey had mapped in detail many of the coal beds of the upper Cretaceous showing erosional and structural conditions. There is direct proof that several of the present producing fields were first located by the evidence shown in the Cretaceous coal reports. After the structures were located in the Cretaceous, the detailed work was not difficult.

Later, the sketch maps giving approximate contours of a great number of possible oil structures in Wyoming were valuable, since they were issued promptly, and gave sufficient information to enable a decision as to whether the expenditure of money in more detailed work was justified.

The Big Muddy Oil Field and the Baxter Basin Gas Field were probably due more to favorable government geological reports, than any other factor. Prospectors lacked the courage until a few months after a favorable U. S. G. S. report was issued. The Baxter Basin Field remained idle for several years after the drilling of several wells on a minor flexure of the structure, until the Survey issued a report giving evidence by contours, that the highest part of dome had not been tested. Recent tests have developed tremendous gas wells with some lower sands still untested. There are other fields which might be mentioned.

In conclusion, the history of oil development in the Rocky Mountain Region proves that the work of the United States Geological Survey has been of considerable economic value.

WHAT THE OIL COMPANY EXPECTS OF THE GEOLOGIST

ROBERT S. ELLISON¹

Like any worth while subject, the one assigned to me affords opportunity for valuable discussion beyond the limits of this occasion. It is desirable, therefore, to confine my present consideration of the subject to a few points that appeal to me as involving the primary value of the petroleum geologist in the growth and maintenance of the petroleum industry.

In approaching the subject, I assume that the worth while producing and operating concerns in the business are exerting at all times their efforts and resources in the search for new commercial deposits of oil or gas, and at the same time are earnestly endeavoring to operate both economically and profitably the producing properties they hold and which legitimately must bear the burden of additional discovery and exploration work.

I realize that the usefulness and activities of the geologist depend in large degree upon the same factors as in other professional men. First in order, he should possess the homely but God-given quality of common or horse sense. Next, he should have all of the worth while technical training and study within his means. Finally, he should have as much practical work and experience as the limits of his years and opportunities can provide him. Then, in my judgment, and only then, is his opinion, either written or oral, deserving of the large amounts of money which are being expended more and more upon such opinions.

Those are broad, general rules and are marked by the usual exceptions, I am glad to be able to say, at least as to one or the other of the last two factors named. In any event, the geologist, or perhaps more fittingly phrased, the geological department, of any worth while oil company occupies today,

¹Vice-President, Midwest Refining Company, Denver, Colo. This paper was read before the Denver meeting of the Association.

and in my opinion will continue so to occupy, an integral part of the organization and the heads of such department must be looked upon by the executives of any such company as right-hand men in the organization.

This does not mean even today that an oil producing concern cannot be built up and cannot successfully do business without an elaborate geologic force or without any geologists at all, for there are practical oil producers who can follow the lead of others, particularly in favored sections, and can succeed on a limited scale. For any extended operations either in point of time or over considerable areas, I would hesitate to undertake to pilot any concern, however, without loyal, competent, experienced geologists.

Having expressed my personal view, it is fitting that I define more definitely perhaps what to my mind is desired and sought by those responsible for the continued growth and expansion of a company, and for the proper expenditure of its funds in such connection. Certainly no wildcat drilling should be undertaken without the considered, written report of the responsible geologist. To my mind the ideal report of a geologist to the proper executive of his company must be something more than an opinion or a recommendation. It should be a carefully prepared, technical report, giving in sufficient detail the data upon which the geologist has based his judgment, so that the executive, or any other competent person, may independently review the facts or observations submitted and decide whether sound conclusions have been drawn from them. A trained geologist who has approached a problem with an open mind, made careful observations in the field, recorded them in such a manner that another geologist months or even years later may verify them on the ground, and presented them in a carefully written and logically reasoned report, has done a valuable piece of work for his employers, which is worthy of a permanent place in their records.

Failure to attain, or at least to approximate, such standards can only bring the geologist and his profession into deserved disrepute and contribute to needless waste and loss in operations. The oil industry has been, and perhaps always

will be, subjected to the more or less deserved criticism, in connection with wildcatting particularly, of being wasteful and extravagant. I do not consider it sufficient to meet this criticism by the sole reply that it is unavoidable and inherent in the business. I believe it can be and is being met by requiring more diligent, conscientious and intelligent work on the part of the geologists, and more careful and intelligent study of such work on the part of the executive. Certainly, this latter policy is already in many instances resulting in more acreage being declined than is accepted for drilling. Of course I am not now speaking of the stock promoter or of the fellow who preaches that an entire state like Wyoming, for instance, is underlain by vast oil pools merely waiting to be tested. I refer only to those companies striving ever to place their operations on a more efficient and business-like basis, and which are not content to find after an expenditure of \$75,000, or more, on a dry hole that the loss could have been avoided by more thorough, intelligent geologic work and careful consideration of same.

In this connection, the quality of keeping an open mind on the part of the geologist is too often ignored. Necessarily he must form conclusions and is expected to state them definitely in writing, as otherwise his responsibility would be slight, but the geologist who refuses to be convicted of error by the drill or by more accurate, careful work of other geologists, for example, is riding for a fall and frequently loss of position. It is only the man with an open mind who can truly profit by his mistakes, and as long as they do not exceed two out of five he is fairly assured of the confidence of his employer. We all make mistakes but the successful man neither magnifies nor minimizes them. He capitalizes them in his future work and turns into profit what would otherwise have been total loss.

I believe that the geologic examination of any area should in the first instance be undertaken usually at the direction of the head of the land department of the organization, or of such other proper executive as may be following that activity of the company. It is hardly desirable or fair to the geologist to be given simply a roving commission unless the general

purpose of the company or the particular circumstances at the time require that such be done in order to meet competition or for general reconnaissance work.

Very few geologists can hope to have sufficient opportunity to embody all of the different factors which must be available in making a worth while business of finding new structures or sands to prospect. There should be present in passing upon such matters the practical experience of the production head—the man who has actual charge of drilling and developing oil and gas, as well as the advice of those familiar with the transportation and marketing of such products when found. In addition to these, of course, there must be had the judgment of the executive or committee responsible for financing all important ventures of the company. The question of depth, of drilling costs, of actual operations, such as transportation, fuel, water and weather conditions, should all be considered and passed upon not by the geologist alone but by his associates in the other departments just mentioned. If this be true it necessarily means, to secure the best results, a close and friendly co-operation between the geologists and what are usually termed the producing and executive departments. No organization can be built or endure, in my judgment, without mutual confidence and respect among those charged with an important activity. This is true not only in the discovery and testing out of new structures where the geologist should check closely the drilling developments for confirmation of or variance in his original report, but should continue into the more settled and definite operations of a proven field.

With the successful completion of a commercial oil and gas well on a structure recommended by the geologist, it is important for him to assist in outlining a program providing for the least expenditure of time and money in definitely proving the productive area of the structure. The furnishing of information on subsurface geology, by careful correlation of well logs as drilling progresses in any field, is also of great importance to the Producing Department.

These things, to my mind, must mean a continued demand for qualified, worth while geologists. In fact, they call for

something more than a geologist. This has been true for some time and undoubtedly will lead more and more in the future to an even broader, more important advancement for those so adapted or fitted than if one's activity be limited solely to strictly geologic work. One splendid evolution from the geologic ranks is the petroleum production engineer or technologist, whose views and judgment are required and invaluable not alone in the first development of a prospective oil field but even more and more so as the problems of securing oil in the face of increased difficulties becomes more and more pronounced. Another important asset of any geologist of today is the ability not only to size up the geology of what may be an oil structure and be fairly familiar with the costs and problems of developing and operating same, but particularly in the case of new territory it is most valuable if the geologist is familiar with the proper procedure and means of securing leases or contracts upon fair and mutually satisfactory terms from the owners of the lands involved.

I appreciate that this is not at all vital or necessary in the discharge of a geologist's duty, or of particular value in case he is simply retained to pass upon structures or leases already held by his employer. Speaking frankly, however, it appeals to me that the ideal sought by most large companies with which I am familiar is embodied in the man who can be relied upon to protect and safeguard his company's interests not only in the actual finding, working out and passing judgment upon a prospective oil structure, but if occasion requires in the absence of more competent assistance, of securing leases subject to the executive approval and of passing upon, in a practical and understanding way, the actual operating and development problems involved. Such a man as this must invariably be a right-hand man in any worth while organization and his compensation is bound to correspond with such position.

This opens up a question of undoubted interest to all members of the geological profession and one which, in my mind, must be settled along certain fundamental lines. It is no doubt natural for a man hired for and charged with the responsibility of finding new oil deposits to feel that if he

can do this successfully for anyone else that he can do it as well for himself, or if he is of a cautious type he may naturally feel that he at least should have an interest, in the nature of a royalty, in any new structure located for his employer and at the same time receive his assured salary. I assume that this perhaps is a natural feeling and may be augmented by the private opinion, publicly expressed, of some of his friends. My opinion, however, is that the man who allows himself to feel that such should be the case cannot hope to develop along satisfactory lines with any worth while concern. He must work loyally and whole-heartedly for his employer the same as the man in the producing, the accounting, the legal, the sales, the manufacturing or any other department of the business. If he cannot do this happily and whole-heartedly, then he owes a duty to himself and his employer to sever their relations and go out and "get rich quick on his own hook." My judgment is that some men can do this. On the other hand, statistics will undoubtedly show such an enormous fatality among those who do endeavor to follow this course that we can reasonably expect to continue to have among our geologists the same type of trained, loyal, competent men as are found in the other departments of any successful company.

I believe that one of the greatest pleasures in any man's life is to be engaged in any work which he enjoys, which interests him and from which he receives adequate compensation for the needs of himself and his family, including those things which to an educated mind are as necessary as meat and drink. I think it is also true that the science or profession of geology calls for a type of men who take this interest and who receive their greatest pleasure in following the usual duties incident to the terms of their employment.

The degree of advancement or enlargement of scope beyond the geologist's ordinary duties, as well as the compensation paid for same, must depend more or less upon the same factors for growth or advancement as in any other line of work. If he possesses in sufficient degree the three principal factors first enumerated in my remarks and so desires, I would say unhesitatingly that he has ample opportunity for enlarging

his activities logically into the land or producing departments of his company, where with a more actual grasp and understanding of the problems of handling men on a larger scale, and the expenditure of large sums of money and the necessity of securing adequate returns therefor and thereon, he can easily head for the highest position within the gift of his company. This is a matter as in any other profession or business, depending upon the desire, the opportunities offered and the ability of the man himself. On the other hand, I can readily conceive of his remaining active in his chosen profession and attaining such reward and renown as must satisfy his every ambition, and after all, perhaps, no man can hope for greater success than that.

GEOLOGICAL WORK IN THE CARPATHIANS

WINTHROP P. HAYNES

INTRODUCTION

Several geological trips made in parts of the Carpathian Mountains in the company of Galician or Czech geologists during the spring and summer of 1922 have enabled the writer to become familiar with their publications, method of work, and some of their problems.

Inasmuch as the chief oil fields of Central Europe lie in this region some reference to recent literature may be of interest to American geologists, comparatively few of whom have had opportunity of working in the field with Central European geologists.

RESUME OF CARPATHIAN GEOLOGY

TOPOGRAPHY

The great chain of the Carpathians is generally regarded as commencing north of the Danube near Pressbourg (Bratislava) Czecho-Slovakia, and extending in a great arc eastward and southward to the Portes de Fer where the Danube cuts through the chain in western Roumania. This great arc is easily subdivided into three parts which differ in trend, vertical and horizontal extent, features of relief, stratigraphy and structure. (See map I).

1. *The Northern Carpathians* extend from Pressbourg to Dukla Pass and are a complex mass with a series of chains of alpine structure with a general E-W trend in the northern part, and ranges of metamorphic and igneous rocks farther south, which give rise to very diversified topography. The highest range is the Tatra Mountains, chiefly granitic, with a maximum altitude of 2663 meters (8633 feet).

2. *The Central Carpathians* extend from Dukla Pass to Buzeu Pass and are of more simple types consisting chiefly of a series of NW-SE chains formed of the Flysch formations. A doming in the central portion has brought the crystalline rocks to the surface. The mountains are much lower and less rugged in this zone.

3. *The Southern Carpathians* extend from Buzeu Pass to the Danube at Portes de Fer in a general E-W direction and differ widely from the others, owing to the predominance of crystalline rocks. Although the peaks are lower than in the

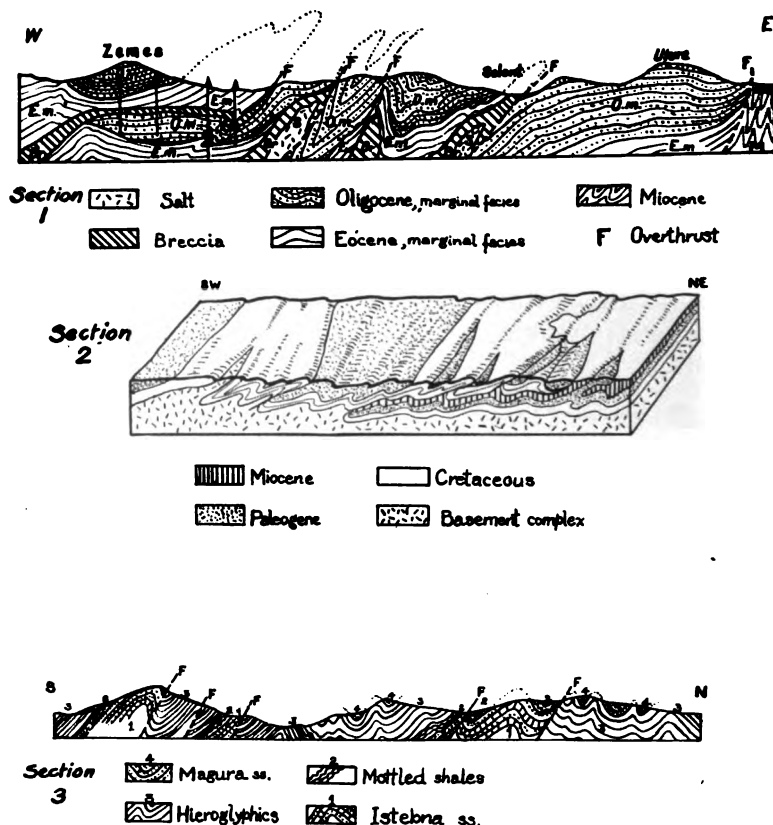


Figure 1, Section 1. West of Zilina, Moravia and Slovakia. Section 2. Southwest from Nadworna, Galicia and Carpathian Russia. Section 3. West of Bacan, Roumania.

Tatra those exceeding 2,000 m. (6500) feet are much more numerous than in any other part of the Carpathians. This portion was formerly called the Alps of Transylvania.

GEOLOGY

The Northern Carpathians are divisible into three geologic zones: (1) an outer zone composed of sandstone and shales

and marls of Cretaceous and Early Tertiary ages which forms the main mass of the Carpathians, (2) a middle zone consisting of a complex of formations, with a basement chiefly of metamorphic rocks overlain by Permian and early Mesozoic strata, and (3) an interior zone of Tertiary volcanic rocks¹.

The Central Carpathians are composed of zones 1 and 3, but near the central and southern end the crystalline complex of zone 2 reappears.

The Southern Carpathians are almost entirely composed of zone 2 with the Flysch of zone 1 along the eastern and southern part.

Stratigraphy

The following table (A) gives some of the major subdivisions of the Carpathian Flysch (Cretaceous and Tertiary) encountered in zone 1, and also in the sub-Carpathian border zone beyond the mountains.

It is impossible to make exact correlations at present or to give detailed stratigraphy here. This table merely represents a general approximation for the various portions of the Carpathians, compiled by the writer from the latest data available.

Structure

The three structure sections accompanying this report are selected to show the characteristics of the structure in the Flysch (zone 1) of the different parts of the Carpathians. (See Map I for location of sections).

Section 1 is based on work of the Czech geologist, Dr. Kettner and shows his interpretation of the structure in a part of the northern Carpathians in Moravia. Section 2 is a composite section after the Polish geologist Dr. Nowak, and shows the general structural features of the northern part of the central Carpathians in Galicia. Section 3 is after the Roumanian geologist, Dr. Voitești, and shows his interpretation of the structure of the southern part of the central Carpathians in Roumania.

GEOLOGICAL WORK

Owing to the extremely variable topography of the Car-

¹The High Tatra Mountains are an outlier chiefly of crystalline rocks of zone 2 in zone 1. (See Map I).

		West		East		Roumania	
		Levantine		Eastern Galicia			
		Gravels					
NEOGENE	Dacic	not recognized				Conglomerate, sandstones, marls	
	Pontic	Congerla beds				Conglomerate, sandstone, marls (oil horizon in Fresh and brackish water; lignitic Moreni and Balcoi fields)	
	Maeotic	not recognized				(Marine and brackish water) (oil horizon in Sandstone and clay marls Buteanari and Campina)	
	Sarmatian	sands, marls and clays		Cerithium beds		Clay marls, oolitic limestone, gypsum and salt Sandstone and marls, some gypsum	
	Tortonien	" "		Salt formation		Sandy marls and sandstone, tuffs	
NEOGENE	Helvetien	2nd Medit.		(Sub-Carpathian)			
	Burdigallen	sands, marls and clays		Red Clays		Conglomerate and sandstone	
PALEOGENE	Upper	Magura sandstone		Great Unconformity			
	Oligocene			Dobrotow beds			
				Kroano beds			
				Sioboda conglomerate (locally)		Menillite slates, bituminous shales "Meletta" beds, Kliwa sandstone (locally)	
	Lower	Hieroglyphic beds		Menillite slates		Conglomerate and Foraminiferal marls	
PALEOGENE				Kliwa sandstone (locally)			
				Menillite slates			
				(chief oil horizon Boryslaw)		Unconformity in East	
	Eocene			Hieroglyphic beds		Hieroglyphic sandstone series (given local names)	
				Pasieczna limestone (locally)		Sandy marls and limestone with "Nummulitica," Lutetian age (Middle Eocene)	
CRETACEOUS		Mottled shales		Mottled shales (sandstone locally)			
				Cieszkowice sandstone (locally)			
	Senonian	Unconformity Istebna sandstone		(not recognized)		Marly sandstone with Inoceramus. (Mingling of Northern and Alpine faunas)	
CRETACEOUS				Jamna sandstone		(Poorly represented)	
	Turonien	Inoceramus beds		Inoceramus beds		Conglomerate and sandstone	
	Cenomanien			Roplanka beds (Inoceramus)		Gedulia sandstone (mingling of northern and Alpine faunas)	

	West	East	Eastern Galicia	Roumania		
	Levantic	Gravels				
Pliocene	Dacic	not recognised		Conglomerate, sandstone, marls (oil horizon in Fresh and brackish water; lignitic Moreni and Sandstone and marls Balcoi fields)		
	Pontic	Congerla beds		(oil horizon in Marine and brackish water) Buteanari and (Fresh and marine) Campina)		
	Maeotic	not recognised		Clay marls, oolitic limestone, gypsum and salt Sandstone and marls, some gypsum		
Miocene	Sarmatian	sands, marls and clays	Cerithium beds			
	Tortonien	" "	Salt formation	Sandy marls and sandstone, tuffs		
	Helvetien Burdigalien	2nd Medit. sands, marls and clays	(Sub-Carpathian)	Conglomerate and sandstone		
Oligocene	Upper	Magura sandstone	Great Unconformity			
		Hieroglyphic beds	Beloveza beds	Dobrotow beds Krosno beds Sloboda conglomerate (locally)	Menilite slates, bituminous shales "Meletta" beds, Kliwa sandstone (locally)	
		Lower		Menilite slates	Menilite slates Kliwa sandstone (locally)	Conglomerate and Foraminiferal marls
						Menilite slates (chief oil horizon Boryslaw)
					Unconformity in East	
Eocene			Hieroglyphic beds	Hieroglyphic sandstone series (given local names)		
			Pasieczna limestone (locally)	Sandy marls and limestone with "Nummulites," Lutetian age (Middle Eocene)		
Cretaceous		Mottled shales	Mottled shales (sandstone locally)			
			Ciekowice sandstone (locally)			
	Senonian	Unconformity	(not recognised)	Marly sandstone with Inoceramus. (Mingling of Northern and Alpine faunas)		
		Istebna sandstone		(Poorly represented)		
	Turonien	Inoceramus beds	Ropianska beds (Inoceramus)	Conglomerate and sandstone		
	Conomanien			Godula sandstone (mingling of northern and Alpine faunas)		

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pathian region there is a great difference in accessibility and many parts have remained practically unstudied up to the present. The steeper mountain slopes are almost universally covered with a dense growth of evergreens and hard woods while the broader valleys and gentle foot-hill slopes are extensively cultivated. In consequence outcrops are frequently lacking over wide areas.

To add to the difficulty of geological mapping the formations are of the peculiar facies known as the Flysch, already briefly described. These littoral and shallow water sandstones and shales are extremely difficult to subdivide owing to great similarity in lithologic character and almost complete absence of index fossils or in fact any fossils of recognizable character in the northern facies. Still further difficulties are due to complex folding, including many overthrusts.

Early Work

The geological work previous to the present century is nearly all of a very general nature and the old Austro-Hungarian maps have very little value. General subdivisions such as the "Carpathian Sandstone" are used on these old maps and include sandstones of Cretaceous (Jamna sandstone) and Oligocene (Magura sandstone) ages.

It is obvious therefore that most of the older literature and maps must be discarded and only the work of the 20th century geologists considered.

Recent Work

Roumania. The most active men in the Carpathians of Roumania with whom the writer has come in contact are Drs. Louis Mrazec, director of the Geological Survey of Roumania, G. M. Murgoci and I. P. Voitești. These men have all been making some very valuable contributions during the past ten years. Some of their most important publications are listed below. All of these geologists are anxious to exchange publications with Americans. The best general reference on the Geology of Roumania is the report by Dr. Voitești "Aperçu général sur la géologie de la Roumanie." August-September 1921. Boucharest. Ann. des Mines 4e Année No. 8-9. This contains an extensive bibliography on Roumanian Geology.

(A full translation in German with text figures has appeared in the *Petroleum Zeitschrift* Vol. XVIII, Nos. 14-20 May-July 1922.

In the same number of the *Ann. des Mines* is an interesting paper by Dr. Murgoci entitled "Nouvelles données relatives aux Gisements du Pétrole." Dr. Mrazec's numerous papers are all listed in the bibliography noted above.

Galicia. The Government Geological service dating from the close of the war had in its petroleum branch for a year or two a corps of very capable young men, chiefly trained in Switzerland, who were doing some excellent work in the Galician Carpathians and in the oil fields of the foothills region. Later, lack of funds caused them to cut down on their force and many of these men have now left to join the various oil companies.

At present the Director, Dr. Jan Nowak, Karkow, Wolská 14 Poland, a most capable geologist, has only a small force of two or three men remaining with him. He has a fund of information on the Geology of the Galician oil fields and the Carpathians. Some of the more important publications from the point of view of petroleum geology by him and his colleagues are listed below.

Nowak, Jan.:

"Le pétrole des Carpathes Polonaises sous le point de vue de la géologie regionale." Lemberg 1921. Roemer's *Travaux Géographiques*. Vol. VI.

"Über die tektonischen Bedingungen des Erdölvorkommens in den polnischen Ostkarpathen." *Petroleum* Bd. XI. 1918.

"Les Unités tectoniques des Carpathes orientales Polonaises" 1914, Lemberg.

Tolwinski, Konstanty, Director of the State Petroleum Research Bureau at Boryslaw.

"Dislocations transversales et directions tectoniques des Carpathes Polonaises" 1921, Lemberg. Roemer's *Travaux Géographiques*, Vol. VI.

"Les gisements pétrolifères et les eaux souterraines en relation avec la géologie de Boryslaw" 1922, Krakow, *Bull. No. 5*, P. U. N. Stacja Geologiczna W. Boryslawiu.

Zuber, R. Prof. Univ. of Lemberg.

"Flisz i Nafta." 1918, Lemberg

These and numerous publications on various subjects by

other Polish geologists can easily be obtained by writing to these men and offering them American reports and books in exchange.

Czecho-Slovakia. Previous to the war most of the geological work in the northern and central Carpathians was done by Austrian and Hungarian geologists. V. Uhlig's "Bau und Bild der Karpathen" published in Vienna in 1903 and now unfortunately out of print is a well known general reference. Later reports by Uhlig and others have appeared in various Vienna publications and can generally be obtained through R. Lechner, bookseller of Vienna.

Since the war the Austrian and Hungarian governments have been cut off from the Carpathian region by the creation of Czecho-Slovakia and enlargement of Roumania and therefore very little has been published by any of their geologists on the subject.

Dr. W. Petraschek, of Leoben, Austria, published an interesting article in the *Petroleum Zeitschrift* for August 1, 1922. Vol XVIII, No. 22., on "Neue Erfahrungen und Richtlinien zur Erdölgeologie in the Karpathen"; but he and the other Austrian and Hungarian geologists are now practically cut off from work in the Carpathians owing to the new political boundaries and unfavorable rates of exchange on Austrian and Hungarian money. In consequence a great field has been opened to the Czech geologists who previous to the war were almost entirely trained in economic and structural geology in Bohemia and also in paleontology and stratigraphy in the famous Barrande basin.

They are now expanding their work and becoming familiar with the Flysch formation of Moravia and making a few trips into Slovakia. Eastern Slovakia and Ruthenia or Carpathian Russia are very difficult to reach from Prague, the capital of Bohemia, and therefore up to the present no attempt has been made by the Czecho-Slovakian Geological Survey to do any field work in this region.

The Geological Survey, under the directorship of Dr. Cyril Purkyně, has recently published several reports dealing with the geology of the northern Carpathians.

Some of these recent reports by Dr. Radim Kettner, Professor at the Technical University at Prague, Karlovo Nám. 19., and his assistants are published in Vol. II Pt. 1. of the Survey Reports.

Geology of the Petroleum Deposits of Bohuslavice and Vlárrou.
Etudes géologiques dans le Flyche Carpathique á la frontière
Moravo-Slovaque.

La géologie du gisement de naphta près de Turzovka en Slo-
vaquie.

Many short articles of historical nature relating to oil in the northern Carpathians written by Prof. J. J. Jahn and Dr. E. Schnabel of Brünn have appeared in the Petroleum Zeitschrift during the past year in Vol. XVIII.

SUMMARY

Difficulties due to the presence of political boundaries have cut down the scope of work and tended to keep the geologists of each country isolated, thereby preventing their studying typical sections in neighboring countries. This has led to many disagreements in correlation which can probably be in great part settled by a little co-operative work.

A great step in this direction was made at the Geological Congress in Brussels in August 1922 when the delegates from all of the Carpathian countries conferred together and organized a Carpathian Sub-Section of the Geological Congress which is to meet once a year to discuss problems of Carpathian Geology and arrange for some excursions.

One of the first duties of this organization is for each delegation to take up with its government the question of granting some sort of special permits for visiting geologists of the other Carpathian countries.

A Committee was chosen composed of one representative from each of the countries as follows: Roumania - Murgoci, Serbia and Croatia (Yougo-Slavia) - Petkovic, Poland - Nowak, Czecho-Slovakia - Kettner.

METHODS OF FIELD WORK

The geologists of Galicia and Czecho-Slovakia working in the northern and central Carpathians have a very good set of base maps to work on, made by the old Austro-Hungarian

Government and reprinted and somewhat revised by the new governments. These maps are the regular hachure-contour topographic maps in black at 1:75,000 and with enlarged quarters at 1:25,000, and the sheets at 1:200,000 with forest areas in green and hachures in brown and rivers in blue. For detailed mapping the maps at 1:25,000 are used exclusively and have proved very satisfactory.

In northern Carpathians most of the work has to be done on foot following the stream beds and dips and strikes are plotted on the map by means of the customary symbol. Colored pencils are used to indicate the formations and the map is colored in the field as the work progresses. Localities of interest are noted on the map with a letter and number and notes made and perhaps a section drawn in the notebook. Owing to the prevalent steep dips this method of mapping is satisfactory and results in a geological map whose accuracy depends largely upon the correctness of the identification of the various formations.

Where outcrops are widely scattered and the formations are similar in lithologic character and lack fossils many different interpretations of the geology may be given by geologists working in an area and it requires co-operative work to establish the correct solution of the problem.

There is a tendency for the Galician geologists, trained in the Swiss school, to explain their geologic features by extensive, unusually flat-lying overthrusts, while the geologists of the Bohemian School employ commonly reverse faults of steep dips.

The writer has noticed there is a general tendency for the geologists who have worked in the Carpathians to question and frequently to discount the work of others. This is quite in contrast with their general courtesy shown to a visiting geologist. The writer has always been cordially greeted and given free access to maps and reports and personally conducted on field trips to interesting areas.

GEOLOGICAL PROBLEMS

Besides the general problem of mapping in detail the Flysch and solving its structural complexities there are two big

problems on which some of the geologists mentioned are working.

Salt Formation. Dr. Voitești has been especially engaged with the problem of the origin of the salt beds and salt domes in Romania. This salt is found all along the Sub-Carpathian zone in greater or lesser amounts and so it also interests the Galician geologists.

The relation of the oil to the salt is also receiving considerable attention in Romania.

Salt Water Problems. Dr. Tolwinski has been collecting sub-surface data on the salt water invasion in the fields about Boryslaw through his research bureau, and has published some important papers on the subject.

Sept., 1922.

Prague, Czecho-Slovakia.

SOME GRAPHICAL METHODS FOR APPRAISING OIL WELLS

By PAUL RUEDEMANN¹

The problem confronting every engineer when planning the details of a large appraisal task is how can the efficiency be increased without hazarding the ultimate results. There are many steps in large valuations which can by proper organization and careful study be made the most simple instead of the most tedious part of the work. Perhaps no one part requires more time than the computations incident to the valuation of future recoverable production after all predictions and estimates have been made. There are many others that can be simplified but will not be dwelt upon in this article as the purpose is to discuss certain charts in connection with the part mentioned.

The necessary procedure in all appraisal work if done by the Annual Analytical Method is (1) to construct curves suitable for estimation of future reserves, (2) to ascertain probable future production of each well from the proper curve, (3) to predict future prices, (4) to predict future cost of operating (5) to chose a satisfactory discount rate and (6) to determine cost of development on locations not yet drilled. These are the primary requisites. There are, of course, numerous less important points to consider which are more or less dependent upon the purpose of the appraisal and the conditions under which made. For any well, having made all the necessary estimates the final step is to combine these and obtain the result, which is the present worth of the well.

The work mainly required in the calculation is first, to determine the future production of the well; next, to read the future price corresponding with each year's production; third, to multiply these together in order to obtain the gross yearly value; fourth, to list the cost of operating the well for each year shown; fifth, to subtract the cost of operating and se-

¹Geologist and appraiser—Johnson, Huntley & Somers.

cure the net future revenue anticipated each year; sixth, to list the discount factor to be used for each year and by multiplication obtain the present value and lastly to total the yearly present value and get the total present value. For a well of ten-year life 71 operations are normally required to get the result.

By having the prices and cost of operating previously discounted, one step can be eliminated but that is all. It requires two persons, one tabulating and reading and the other multiplying to make any progress by a calculating machine. Considering the time for listing production, prices, costs and results in addition to the computations, at least twenty minutes are spent for a well of more than ten-year life. A thousand such wells would mean forty-two working days of eight hours each for two people. Thus it is evident that there is a possibility for shortening the labor.

With this in mind a group of graphical methods were developed which could be used as the conditions warranted. In many cases instead of forty-two days for two persons the work could be done in ten to twenty days by one person and frequently less.

Three types of charts are presented:

1. All valuations as of a fixed date.
2. Valuations of variable dates not sufficient in any group to justify use of method (1), and the chart one where all readings are directly plotted.
3. As in (2), but a part of the factors are computed and certain readings refer to dates and not amounts.

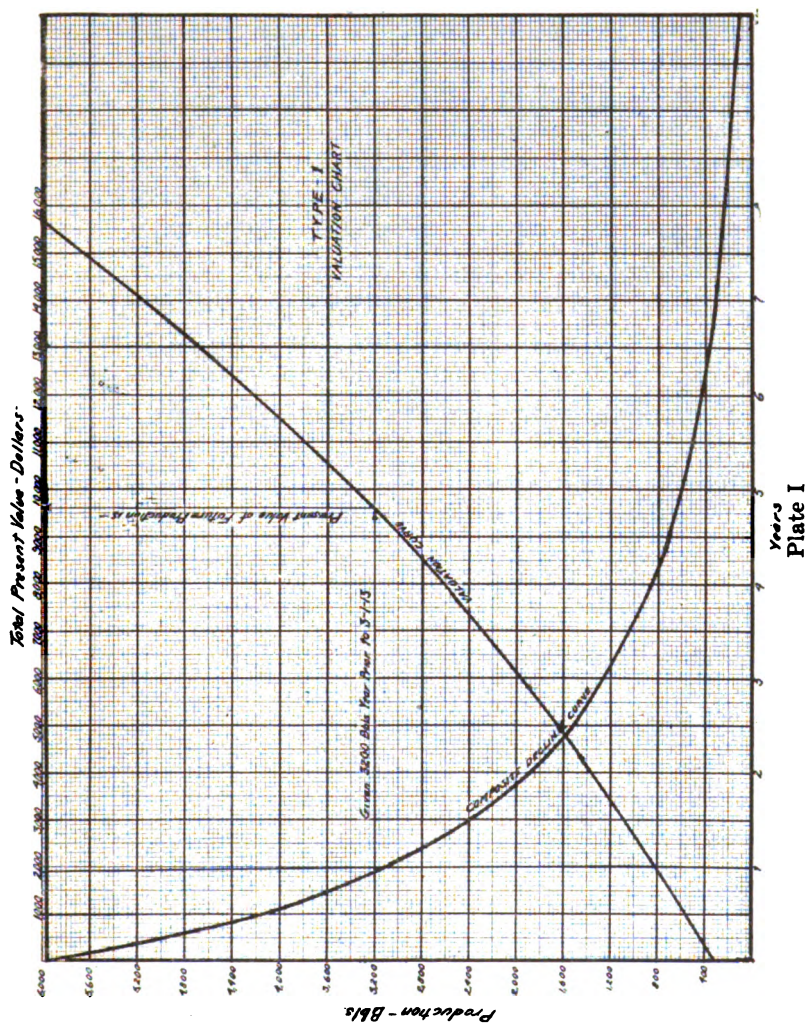
All charts are constructed using operating cost on a well-year basis. This is the most difficult but most accurate way.

TYPE I. ALL VALUATIONS AS OF A FIXED DATE

The simplest form of chart possible is one in which the total present value can be secured in one operation. This is possible only when a composite decline curve is being used for estimating future production and all the valuations to be made are as of a fixed date. March 1, 1913 is a common fixed date in making valuations for Federal Taxation purposes.

Assuming that a composite decline curve is used, it is evi-

dent that by separate valuation of each well much work is duplicated. As the amount of production is dependent upon



the size of the well, wells of equal size will result in the same value.²

²Refinement of size-age is omitted in this discussion although the problem can be applied with the same practicability where age of well is considered.

From any composite decline curve valuations of a series of wells should be made each year smaller by a year or more of production than the previous one. As a rule, about eight wells will suffice. The future production can be read in relation to the total for the year prior to date of valuation; the average per day on date or some other convenient amount. By plotting the size on the ordinate and the total present value on the abscissa, it will be found that the points arrange in a curve or straight line. Thus, by knowing the size of the well, its value can be found by reading from the graph.

The chart, Plate I, is an illustration of the fixed date valuation curve. For the purpose of this article the computations were made by slide rule and not with the usual required exactness. No price or cost changes have been postulated, although both should properly be considered. The computations for the curve are as follows:

Production Year Prior to date, Valuation. Bbls.	Total Net Present Value. Dollars
6,000	15,633.00
1,900	5,805.00
850	1,996.00
410	490.00

The time spent in constructing the curve is negligible if distributed over the valuations made from the curve. We may therefore compare the actual time consumed in obtaining valuation from a curve with the ordinary computation method. To determine total value, given the size of the well requires but one operation, using the curve; the normal number of operations which are required to determine the total value for a well of ten-year life is seventy-one.

Only one person is required to carry out the work by chart while two are necessary when multiplying by machine. Actual time is two persons twenty minutes each against one person two minutes. Where hundreds of wells are involved this saving means many days. Not only this, but the possibility of errors is almost eliminated. Mistakes in computations to obtain curve are revealed by irregularities in the arrangement of the points. On the other hand, by machine method a well

of ten-year life offers 71 chances for error, any one of which means much time lost in checking and retotalling.

The error in reading from the curve depends upon the scale. By charting on a large sheet, a valuation can be read with a maximum error of two percent plus or minus. This is more accurate than it is possible to estimate future production by decline curves.

As a simplification of graph 3 to be described later, a series of such curves could be constructed for as many years as the composite decline curve can be used. This would mean a series of computations similar to those described but each under different prices and operating costs.

TYPE II. VALUATIONS AS OF VARIABLE DATES. ALL READINGS DIRECT.

This is perhaps the slowest type of chart to use but one of the simplest to construct. The data are all plotted on logarithmic paper for convenience. On quadrille the lines would meet at zero which makes interpolation difficult. Of course logarithmic paper prevents expansion of scale and the inaccuracy increases with increase in size of well. Plate II illustrates a chart of this type which is not arranged with as much detail as is possible. By using various colors for units, fives, tens, and hundreds, the points can be more readily found.

There are three sets of lines (1) cost of operating per well year, (2) net value per bbl. and (3) discount factor. The lines for "cost of operating" are plotted first; on the left of the chart is the scale for production; and in the upper part the cost of operating per barrel. Two or three points can be determined easily for each line. For instance, a 1,000 barrels a year with a \$500.00 operating cost is 50c a barrel, and 100 barrels a year with the same cost is \$5.00 a barrel. By working in tens, hundreds and thousands, the points for each line are quickly found. The lines for "net value per barrel" are plotted next. The production scale already on the left is one guide and a net value scale, at the lower end, is the other. As in the case of cost of operating, all points are plotted as multiples of ten. For example, a net value of \$2.00 a barrel for 1,000 barrels gives \$2,000 and for 100 barrels gives \$200. Having

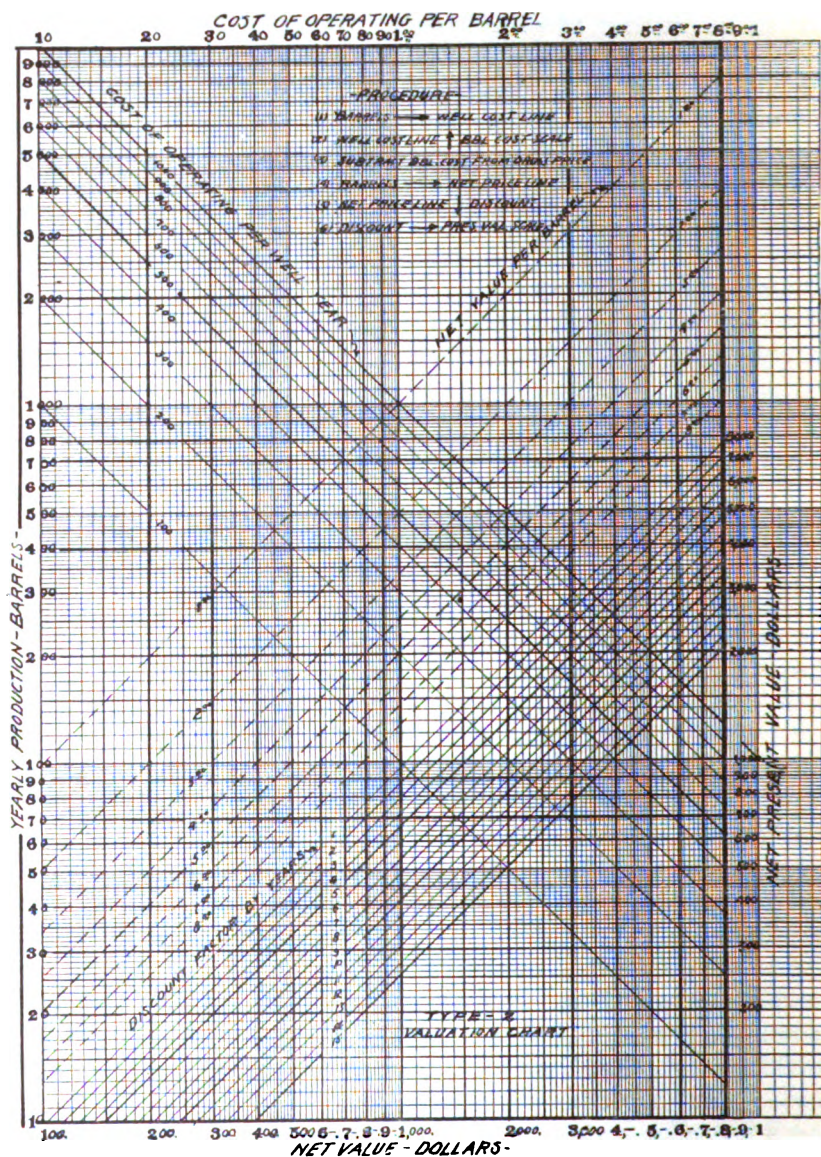


Plate II

the net value it is now only necessary to discount the amounts to find present value. The lower, already fixed scale, and the right hand scale are used, the right scale being the discounted net value. Again the 100, 1,000 and 10,000 lines aid in determining the location of the lines. \$1,000.00 discounted one year at 10% is worth \$953.46 and \$10,000.00 is discounted to \$9,534.60. Similarly the discount factor may be plotted for each other year. As many lines can be drawn as the years in the well of the longest life. Generally twenty are sufficient.

Since net value lines and discount lines are both plotted against the lower scale, in reading it is possible to progress from net value, to discount and to present value without any intermittent reading. Given, for example, the data shown in the following table: to find the net value.

Year	Future Production	Future Price per bbl.	Operating cost per well year
1	2,000	2.20	400.00
2	1,000	2.30	500.00
3	500	2.40	600.00

Start on left scale at the 2000 bbls. production line, move horizontally to right to intersection with the \$400.00 operating cost line, thence vertically upward and read cost per bbl., which is 20c. The future price the first year is \$2.20 less cost of operating leaves \$2.00 net profit. Again follow the 2,000 bbl. line to right to intersection with the \$2.00 net price line, thence vertically down to intersection with 1st year discount line, thence horizontally to right and read the present value, which is \$3,750.00. For the second year begin at the 1,000 bbl. point, read to \$500 cost operating, thence to \$1.80 net price line by interpolation, thence down to 2nd year discount, and thence to right and read present value, \$1560.00. The last year the cost of operating is \$1.20 a barrel and gross price \$2.40 or a net of \$1.20 and the present value \$480.00. The total present value for the three years is \$5,790. By computation the value obtained by computation would have been \$5,845.40, and there is thus an error of 0.9 percent.

Considering the saving in time such an error is warranted. But because of the necessity of referring to price and operating cost tables it is not as practicable as the method to be

described next. The advantage is that it may be applied with any set of production, cost or price figures.

For a well of ten years future life, 61 operations are required as compared with 71 by ordinary calculation. However, the operations by the chart are much quicker because no multiplications are required and instead of two persons with a calculating machine, one person with a chart can complete the work in less time than the two would.

TYPE III. VALUATIONS AS OF VARIABLE DATES. READINGS REFER TO DATE

Three separate diagrams are required to make a valuation, (1) Discounted Price and Production, (2) Operating Cost Check and (3) Total Present Value of Cost of Operating.

The first set of lines of diagram 1, Plate III, consists of curves of discounted future prices and lines of production. The prices are plotted first using a scale on the left for years and a lower scale of discounted price. For lack of room the amounts have been carried out for ten years only. However, the operating cost lines are for a longer period.

The predictions were made in a particular case where war inflation was a factor and consequently show a more rapid increase in the early life which gives the curves a peculiar turn at the lower end.

Having plotted the price curves, it is a simple matter to arrange a scale and the production lines. Using the lower scale of price, decide on the size of the yearly production of the largest well likely to occur in the field and then fix the maximum limit of the right scale of gross present value. This should be adopted in units easily divisible and convenient to read. Two or three points are sufficient to plot each line. The points are readily computed, for instance, 100 bbls. at \$1.00 discounted price is \$100.00 gross present value, 200 bbls. is 200 etc. Similarly 100 bbls. at \$4.00 gives \$400.00, the second point for the 100 bbl. line.

These two sets of lines are all that is necessary to find the gross discounted value of the well. Cost of operating is later deducted to obtain the net value.

As the end of the life of the well is reached the total income

TYPE 3 - VALUATION CHART

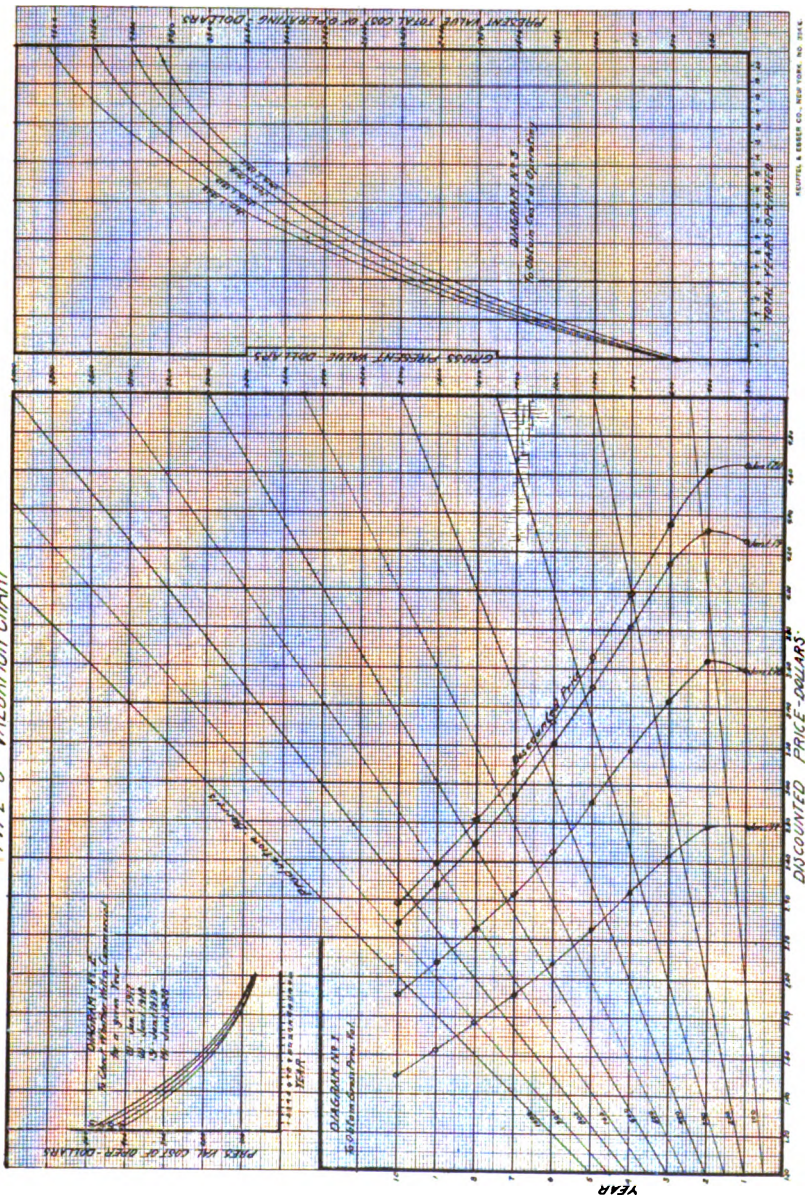


Plate III

may be less than the cost of operating. When this occurs the well has reached the end of its commercial life. Cost of operating is generally computed as an average of all wells. Few companies have the data by leases, and consequently, wells which are normally operated are eliminated due to the averaging. However, the larger wells in the group, by having less than their rightful cost, compensate for the loss and the final results balance.

Diagram 2 is the check of commercial productivity. Each curve represents the yearly future cost of operating as predicted for the date indicated. By discounting several of the costs at the rate being used in the appraisal, sufficient points are obtained to construct a curve. On the lower scale is years and at the left, discounted cost. For instance, the intersection of the vertical line for the tenth year with any curve is horizontally opposite the discounted cost for the tenth year, or rather the present value of the cost ten years hence.

Having determined the commercial life and the gross discounted value, the subtraction of total cost of operating, discounted, results in the valuation desired.

Diagram 3, consists of curves of total operating cost, for any number of years discounted at the rate being used. By multiplying a few of the future costs as predicted for any year by the cumulative discount factor the present value of the total future costs is obtained. The cumulative discount factor produces the same result as multiplying each year's cost by its respective factor and adding the results. This does not hold true for increasing or decreasing cost predictions. In such instances the larger method of separate multiplication must be used. On the lower scale is total number of years and at the right total present value. If the well has ten years commercial life the intersection of the ten year vertical line with the proper curve indicates horizontally to the right, the present value of the total amount to be deducted from gross value.

For the wells completed any date other than shown by the curves, a more accurate result can be secured by interpolation between lines. This is an advantage the graphical method has over the normal one in that a minimum of predictions is required.

Example: A well was completed in January 1918. From the production decline curve for the region the following annual production is estimated:—

1st year	1,000 bbls.
2nd year	600 bbls.
3rd year	600 bbls.
4th year	150 bbls.
5th year	50 bbls.

Solution: Starting in year 1, left scale of diagram 1, thence horizontally to right to price line for January 1, 1918 thence vertically upward to the 1,000 bbl. production line, and thence horizontally to right, read gross value for the first year production. For the second year begin at the two year point of the price curve and follow through as before except that the 600 bbl. production line is used. For the fifth year a present gross value of \$150.00 is found. This is likely to be uncommercial and therefore a check is made. On diagram 2, starting at fifth year line, thence vertically upward to the Jan. 1, 1918 line and thence horizontally to left it is found that it costs just \$290.00 to operate. Thus the fifth year is eliminated and a commercial life of four years used. Next refer to diagram 3. As there are four commercial years, begin at the four year point, move vertically upward to the January 1918 line and thence horizontally to right to the scale and read total present value of cost of operating. The final results are:—

Year	Future Production bbls.	Gross present value \$
1	1,000	3,600
2	600	2,190
3	300	1,075
4	150	1,075
5	50	Not com
		7,675.00
	Less total cost operating	1,475.00
	Present value of well	\$ 6,190.00

In this procedure it is to be noted that no reference was necessary to either future prices or costs. This saves much time as the only date of valuation and future productions are required and the valuation can be made with few operations. For a well of ten years future life there are only 13 operations as compared with 71 by the ordinary procedure. Moreover,

only one person is needed to use the chart while two are at a calculating machine in the longer method. It is safe to say that a saving of from 80 to 90 percent is made in time without impairing the final results. Checks have been made and the maximum error found to be three percent, plus or minus.

In the long run this slight error compensates. At any rate, future production cannot be estimated within three percent and there is thus an error at the outset greater than that introduced by graphical valuation.

Other methods have been developed wherein valuation can be obtained in one to five operations for any sized well and with any type of decline curve, future price curve or operating cost. The charts are in preparation and will be given at some future date.

EDITORIAL

STUDIES IN PETROLEUM GEOLOGY

This number of the Bulletin presents as the leading article a paper by Dr. David White on the subject of co-operation among petroleum geologists in attacking the many problems in petroleum geology which are as yet unsolved, or only partially solved. Examples of the types of research which should contribute largely to better understanding of facts and principles in petroleum geology are cited in Doctor White's discussion. All of the members of the American Association of Petroleum Geologists and scientists who are interested in the development of petroleum geology will, it is hoped, give careful attention to the suggestion that the largely latent capabilities of this great society of workers in a rather young but exceedingly important division of earth science—our Association—may yield definite and very valuable contributions to the advancement of the science by giving attention in as united a way as possible to problems which are presented. It has repeatedly appeared in the meetings of the Association, especially in the discussions following various papers, that information is very frequently available which is of great value, and the statement has been made that few specific questions or problems could be raised on which the members of the Association could not offer from their observations and varied studies some material which would constitute worth-while additions to our knowledge.

With some of the considerations in mind which are here presented by Dr. White, the division of the Bulletin columns entitled Geological Notes was some time ago introduced, in order that opportunity might be presented for recording observations shorter in length and perhaps less formal in nature than those embodied in the papers read before the Association and published in its Bulletin. Doubtless the short contributions which have thus appeared add to the value of the Bulletin to its readers, but it would appear that a vastly greater body of interesting and often very significant information is not prepared for presentation under this head, than might, if specific attention were drawn to a certain line of investigation, be forthcoming. Consequently the suggestion by the Editor that the Bulletin might serve to crystallize the various lines of inquiry in the field of petroleum geology projected by members of the Association, and to serve in a measure as a clearing place for information gathered, has been the basis for the incorporation of a new department or division of the Bulletin whose only function it will be to present subjects of investigation in petroleum geology and allied fields and to record data offered in carrying forward the studies outlined. A definite statement of problems and studies focuses attention upon them, and it is obvious that the membership of the American Association can make a contribution to the science which could not, perhaps, be made in any other way.

This Editorial, following the general thought of the discussion so well

presented by Doctor White, is written to call special attention to the proposal that the members of the American Association of Petroleum Geologists unite to state clearly problems toward which investigation by various workers may be directed, to carry on the study of these and to bring together data which otherwise might never be recorded or assembled. It is proposed to carry in successive issues of the Bulletin a concise statement of problems which are outlined for study, that readers may be reminded of subjects concerning which special help in gathering data is desired. Attention should be directed regularly to this division of the Bulletin and a cordially active participation by all of the workers in petroleum geology will assure the achievement of results.

RAYMOND C. MOORE.

RESEARCH PROBLEMS

TEMPERATURE OF FLUIDS IN WELLS

To the Editor:

For some time I have been collecting scattered data on the temperatures of oil and water coming from drilled wells. This I have been doing with the object of studying and correlating the facts and attempting to arrive at certain definite conclusions, subsequently to be published. I know that many other geologists are likewise gathering information along this line. It is very difficult for any one of us to reach any satisfactory results without assistance from the others. Therefore, in view of the opportunity offered by this new department of the Bulletin, I should like to make an appeal to those who are interested in this problem to send me such data as they feel able to give. I should like to serve as a clearing-house for facts bearing on this subject.

In order to systematize the collection and recording of facts, I suggest the following outline as a guide. For the solution of the problems involved, as many as possible of these questions should be answered:

1. State geographic location of well.
2. On what type of structure is well located (dome, anticlinal nose, terrace, fault, fracture zone, etc.)?
3. How is well located on structure?
4. Was well flowing or on pump when temperature measurements were made?
5. What was production when temperature measurements were made?
6. Is well producing from one or several sands? If latter, was any temperature difference noted in fluid from the different sands?
7. What is lithologic character of producing sand (lime, sand, or shale; fine or coarse; etc.)?
8. To what geological formation do producing sands belong.
9. What is the character of the water or oil produced (chemical composition, gravity, etc.)?
10. Under what conditions of casing is fluid being produced. State size of casing or tubing.
11. Where was temperature measured, at mouth of well, at end of lead line (State distance from well), or inside well (State at what depth)?
12. Is any gas produced with fluid (oil or water)? If so, how much?
13. Have temperature measurements been made at different times in history of same well? If so, what changes have been noted in temperature production, and other conditions? What was amount of production of oil, gas and water each time such measurements were made?

14. State offset conditions and whether temperature changes have been noted bearing any relation of history of offset wells.

Any suggestions from readers of this Bulletin will be highly appreciated. In any published result, credit will be given for data used.

Information submitted by correspondence will be held as confidential, if so requested. I shall be glad to exchange such data as are not regarded as confidential.

F. H. LAHEE.

GEOLOGICAL NOTES

GEOLOGIC SECTION IN WESTERN KANSAS

CHARLES T. LUPTON

During the past summer (1922), the Mutual Oil Company drilled a well 3840 feet deep in the southwest corner of Gove County, Kansas, which is near the middle of the western half of the state. The location is in the southeast quarter of the southwest quarter of sec, 27, T. 15 S., R. 31 W.

Although no oil or gas was encountered in this well, the record of the formations passed through will be of immense value to those doing drilling in other parts of this region. As far as the writer is aware no well has penetrated the Pennsylvanian rocks nearer this locality than the Vesper well in Lincoln County, 132 miles east and 21 miles north. Hence the well in Gove County is in the midst of almost unknown territory, in so far as the detailed character of the formations is concerned.

Log of Well in SE¼ of SW¼ of sec. 27, T. 15S., R. 31 W., Gove County, Kansas

	Feet
1 Blue, gray and yellow limey shales	0— 410
2 Soft white chalky lime (Ft. Hays)	410— 480
3 Blue, dark and brown shale and slate	480— 695
4 Sandy shale (little fresh water)	695— 700
5 Blue, dark and brown shale and slate	700— 795
6 Limestone	795— 800
7 Black shale	800— 850
8 Broken limestone	850— 915
9 Sandstone (water rose 400 feet)	915— 930
10 Broken lime and shale	930— 942
11 Sandstone, dry	942— 968
12 Shale	968—1000
13 Blue shale	1000—1012
14 Gray lime and white slate	1012—1032
15 Sand	1032—1045
16 Gray lime and white slate interbedded	1045—1083
17 Blue slate and shale	1083—1110
18 Sandstone	1110—1140
19 Blue and brown shale and slate	1140—1385
20 Sand (some water)	1385—1400
21 Lime and shale	1400—1454
22 Sand upper part interbedded with shale	1454—1510
23 Brown shale	1510—1540
24 Sand red	1540—1575
25 Shale	1575—1592
26 Sand	1592—1598
27 Red clay and shale	1598—1798

28 Sand (hole full of salt water)	1798—1808
29 Red rock	1808—1825
30 Red sand	1825—1978
31 Red slate	1978—2030
32 Sand	2030—2058
33 Red rock	2058—2180
34 Gravel	2180—2185
35 Red rock	2185—2210
36 Limestone	2210—2250
37 Red sand	2250—2290
38 Red rock	2290—2325
39 White gumbo	2325—2327
40 Red rock	2327—2410
41 Limey sand	2410—2430
42 Blue slate	2430—2435
43 Red rock	2435—2460
44 Limestone	2460—2465
45 Red rock	2465—2490
46 Lime shells and red rock	2490—2530
47 Red slate	2530—2540
48 Limestone	2540—2550
49 Red slate	2550—2560
50 Limestone	2560—2570
51 Blue slate	2570—2581
52 Limestone	2581—2585
53 Red rock	2585—2618
54 Limestone	2618—2658
55 Red shale	2658—2680
56 Red sandstone, shale and clay	2680—3095
57 Black slate	3095—3150
58 Black sandy shale (salt water in lower part)	3150—3230
59 Limestone interbedded with shale	3230—3310
60 Limestone	3310—3350
61 Blue light and brown shale	3350—3485
62 Sandstone hard at top (salt water)	3485—3535
63 Dark shale	3535—3540
64 Sandy shale and hard shells	3540—3640
65 Limestone sandy at base (hot salt water)	3640—3752
66 Sand and limestone	3752—3780
67 Limestone	3780—3840
Total depth	3840

The surface rocks in the locality where the well was drilled belong to the Niobrara shale or chalk. The first 480 feet of the hole (Nos. 1-2), were in the Niobrara. The upper part of this formation consists of blue, gray and yellow chalky shales, whereas the lower 70 feet is a white soft limy chalk known as the Fort Hays limestone.

Underlying the Niobrara chalk, (Nos. 3-8), from 480 feet to 915 feet, is the Benton shale. It consists mainly of blue, dark and brown shale and slate with some limestone interbedded with shale in the lower part. The 5-foot bed of limestone from 795-800 feet may be the equivalent of the Greenhorn member of the Benton.

The Dakota series, (Nos. 9-18,) was encountered from 915 feet to 1140 feet. As shown in the log, it contains four sandstones ranging in thickness from 13 to 30 feet.

Beneath the Dakota is the Commanchean, (Nos. 19-23,) extending from 1140 feet to 1540 feet. The upper 245 feet consists of blue and brown shale and slate and is the Kiowa shale, whereas the lower part, 155 feet thick, consists of sandstone and shale and is the Cheyenne sandstone. The lower part contains two sands, one 15 feet thick and the other 56 feet thick.

From 1540 feet to 3095 feet, (Nos. 24-56,) the rocks are mainly red in color and are classified as Permian, although some Triassic may be present in the upper part. The total thickness of this red series is 1555 feet.

Beneath the Dakota is the Comanchean, (Nos. 19-23,) extending from which was encountered in this well at 3095 feet and 755 feet of this series was drilled through to the bottom of the hole. The character of the formations changed abruptly in passing from the Permian into the Pennsylvanian, as the lower part of the Permian consists of red rock and the the upper part of the Pennsylvanian of black shale and slate. One prominent sand 50 feet thick occurs in the Pennsylvanian 390 to 440 feet below the top or from 3485-3535 in the log. Another bed of sandstone somewhat limy was encountered about 655 feet below the top of the Pennsylvanian, or from 3752 to 3780. It contained hot salt water. From the base of this sand to the bottom of the hole the rock is limestone.

The above interpretation is based entirely on lithology.

K. C. HEALD: In support of Mr. Lupton's statement that the well in Gove County drilled through Pennsylvanian rocks, are findings by P. V. Roundy, of the U. S. Geological Survey. A well in T. 24 S., R. 23 W., Ford County, Kansas, southeast of the Gove County well, yielded cuttings from a depth of 3640-3650 feet containing *Bairdia* n. sp., *Hallina* n. sp., *Amphissites centronatus* var., and *Amphissites* n. sp., cuttings from a depth of 3650-3655 feet contained *Fusulinella* ? sp., *Bairdia* n. sp., *Hallina* sp., and *Amphissites* sp. Mr. Roundy classifies this fauna as "lower Pennsylvanian, but not necessarily basal Pennsylvanian."

OIL POSSIBILITIES OF SOUTH DAKOTA*

With the extension of the search for oil into heretofore unprospected territory some attention has recently been given to the oil and gas possibilities of South Dakota and articles covering the possible resources of

*Published by permission of the Director, U. S. Geological Survey.

the State have been published recently by Roy A. Wilson¹ and A. B. Rowley². Both of these articles fail to emphasize a factor which seems to the writer to merit the most careful consideration in forming an opinion as to the possible presence and location of commercial oil or gas pools within the State, namely, the probable existence of an elevated backbone of pre-Cambrian rocks connecting the Sioux quartzite area of eastern South Dakota with the Black Hills. In the eastern part of the State the Sioux quartzite (or granite) is directly overlain by the Dakota sandstone. This area of direct contact apparently tapers westward to a point located in the neighborhood of Pierre, beyond which point an increasing column of Paleozoic and earlier Mesozoic rocks intervene between the pre-Cambrian and Dakota as the Black Hills are approached. North and south of this backbone of pre-Cambrian rocks it seems reasonable to assume that the pre-Dakota sedimentary column is thicker than above the ridge, and that local unconformities and deformations may be present along the flanks of the ridge. Records of deep wells in critical areas should be examined in the light of this general hypothesis to determine the presence of such an arch in the crystalline rocks, and the areal extent and altitude of such Paleozoic and early Mesozoic formations as may be present.

In another important particular, to some extent related to that just discussed, the reports published by Wilson and Rowley are probably in need of modification. Both reports are accompanied by structure contour maps drawn on the Dakota sandstone, which show the lowest point of the major north-south syncline as lying near Lemmon, South Dakota.

The original data on which the region south and southwest of Lemmon was contoured is to be found on pages 37 and 18, respectively, of the U. S. Geological Survey Bulletins 627 and 691-A. The original contouring of the areas was drawn on the top of the lower member of the Lance formation, and was converted to contouring on the Dakota sandstone by assuming a constant stratigraphic interval between the two horizons of 3,700 feet.

As a matter of fact this interval probably ranges from about 4,300 feet at the northwest corner of the State to 2,800 feet more or less at the mouth of Cheyenne River. This convergence probably does not take place uniformly, and adequate data is lacking to indicate just what the actual variation in thickness of the Upper Cretaceous sediments is. It is, however, believed that the synclinal axis of the Dakota surface will be found to lie a considerable distance west of the Lemmon when drilling has yielded further evidence.

Structural domes along the axis of the supposed arch in the basement rocks are believed to afford the best localities for wildcat tests, as such

¹Wilson, Roy A., The possibilities of oil in South Dakota: *S. Dak. Geol. and Nat. History Survey Bull.* No. 10, 1922.

²Rowley, A. B., South Dakota may be center of wildcat work: *The Oil Weekly*, vol. 26, No. 11, pp. 10-11, 1922.

features may afford traps for oil or gas carried along by artesian flow from the west, and they may also be reflections of more pronounced structural features in the pre-Dakota rocks, some of which may be petroliferous in South Dakota.

W. T. THOM JR.

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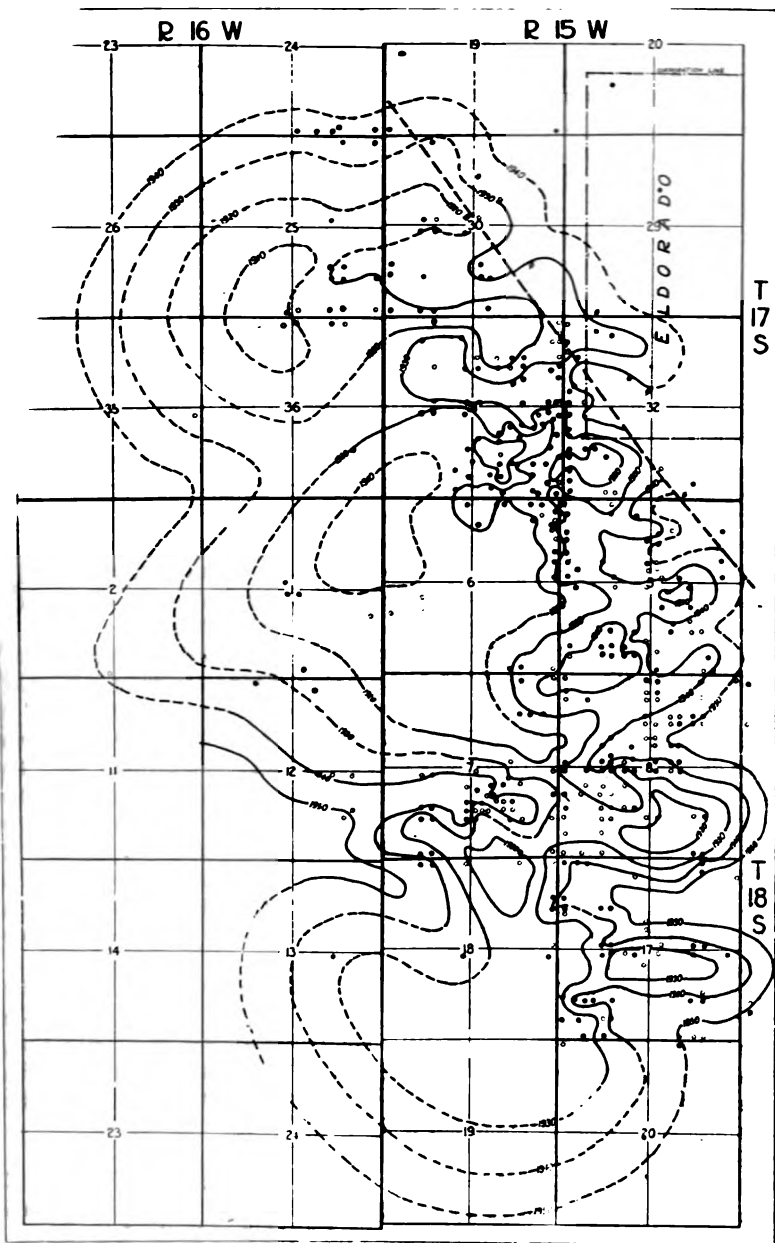


Fig. 1. Subsurface structure contour map of the El Dorado field by the U. S. Bureau of Mines.

REVIEWS AND NEW PUBLICATIONS

El Dorado, Arkansas, Oil and Gas Field. Bureau of Mines, Manufactures and Agriculture, Little Rock, Arkansas

This Bulletin of 90 pages was published by the State of Arkansas during the latter part of June, 1922, and can be secured free. It consists of a paper by H. W. Bell and J. B. Kerr of the United States Bureau of Mines, 68 pages in length, describing drilling and production methods, followed by a reprint of two press notices of the United States Geological Survey by K. C. Heald, et al., and a brief statement of recent developments, 3 pages in length. This is the second publication of the State of Arkansas dealing with petroleum, the first being a report on the mineral resources of the state. Aside from the very unsatisfactory and gaudy cover the Bulletins are very commendable. A map of the field on a scale of 2 inches to the mile and ten other plates are enclosed in a pocket at the rear of the publication.

The contribution by the Bureau of Mines gives a brief history of development followed by a very interesting account of drilling and production methods where special devices had to be brought into use to separate oil from water. For many months a number of wells flowed a thousand barrels or more a day of water and oil, under great pressure, and separation was made possible by the use of chokes and flow lines with bleeders for salt water, the pressure being held back by a reducer at the end of the flow line. In addition, there are methods of dehydration in common use.

Keen competition to make the first geological map of the El Dorado field between the United States Bureau of Mines and the United States Geological Survey resulted in a map by the former Bureau (Fig. 1), published August 18, 1921, by the Conservation Department of the State of Arkansas, at El Dorado, showing a long anticline extending from west of north to east of south, with separate highs in section 36, T. 17 S., R. 16 W. and sections 6 and 18, T. 18 S., R. 15 W. Not to be outdone, the United States Geological Survey issued a press Bulletin, on May 15th, 1922, mapping the geology of the producing area, but not connecting it with the adjacent wildcat wells and made the surprising announcement that the field is not on an anticline. Instead, they show six subsurface faults trending in a northeast-southwest direction and one in an almost east-west direction (See this Bull., vol. 6, p. 362). Following these absolutely divergent subsurface structure contour maps by two official Bureaus, the publication here reviewed unfortunately omitted the geological map of the Bureau of Mines in favor of the Geological Survey.

The general consensus of opinion is that the structure is an anticline with the highest point near the southwest corner of section 31, T. 17 S., R. 15 W., and W $\frac{1}{2}$ of section 6, T. 18 S., R. 15 W., extending southward

Fig. 1. Subsurface structure contour map of the El Dorado field by the U. S. Bureau of Mines.

through the producing area to section 9, T. 19 S., R. 15 W. The oil has clearly accumulated on the east side and in part along the axis of the anticline, especially south of the highest point in section 31. Gas is confined to the highest part of the structure in section 6, T. 18 S., R. 15 W., and section 1, T. 18 S., R. 16 W. As shown in the Bureau of Mines' map there are sharp folds or flexures in the producing sand. These dips have been interpreted by the Geological Survey as faults.

Owing to the abrupt, thinning and thickening of sands in this field, to the inability of most rotary drillers to tell when they are on top of the sand, and to the use of new and old steel lines which give very different measurements at a depth of 2,000 feet, it is not safe to attribute the irregularity to faulting. Moreover, surface faults and a few pronounced subsurface faults are becoming well known in Louisiana and Arkansas such as the subsurface faults through the Homer field and between Bull Bayou and De Soto fields. Besides the surface fault in section 32, T. 17 S., R. 15 W., there is another on the east line of section 1, T. 18 S., R. 15 W., striking northwest-southeast. Other pronounced faults are known in the vicinity of Stephens, Arkansas, near the Hunter well. A number of deep tests have recently been drilled in and near El Dorado field and these have found hot salt water in what is probably the Marlbrook marl at about 2,550 feet. The Frasier well in section 1, T. 18 S., R. 16 W., had an initial estimated volume of forty million gas in this sand at 2,528 feet. Another sand carrying salt water was found by the Humble Oil and Refining Company in SW $\frac{1}{4}$ SW $\frac{1}{4}$ of section 31, T. 17 S., R. 15 W., at 2,650 feet and the same sand was found by Constantin in the SE $\frac{1}{4}$ of section 6, T. 18 S., R. 15 W. The Constantin well reports sand and sandy shale from 2,660 feet to the bottom of the hole at 3,257 feet with two streaks of red gumbo between 3,050 and 3,100 feet. The Cooper-Henderson deep test in section 19, T. 17 S., R. 15 W., reported lime below 3,055 feet, which was believed to be Lower Cretaceous. This well was carefully drilled and cored and the log is more reliable than the log of the Constantin well and the sand in the latter well may really be lime.

The first deep producing well near El Dorado was the El Dorado Nat. Gas Co. well, or No. 1, SE cor. NW $\frac{1}{4}$ sec. 1, T. 18 S., R. 16 W., completed about September 1, 1922, in a sand at 2,948-2,952 feet. According to the Geological Survey this is the Blossom sand which is the producing horizon at Stephens, Arkansas, and Haynesville, Louisiana, and which has shown oil in the Humble Oil & Refining Co. well in sec. 6, T. 18 S., R. 13 W., at 2,975 feet.

The Smackover field, 12 miles north of El Dorado, and the East El Dorado field 4 miles east of El Dorado, produce from the Nacatoch sand at a depth of 2,000 feet in the former and 2,150 feet in the latter.

SIDNEY POWERS.

Tulsa, Okla.

THE ASSOCIATION ROUND TABLE

DENVER MEETING OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

The first regional meeting of the American Association of Petroleum Geologists was held in Denver, Colorado October 26, 27 and 28, 1922. The meeting was a marked success from the standpoint of number and character of papers presented, in vital interest which was sustained throughout all of the sessions for three days, and in point of attendance which was large. Sixty-three papers of high scientific value were scheduled on the program and most of them were presented and discussed in the meeting. Intense interest was manifested and sustained through all the sessions. Toward the close, the discussion had to be limited, but even then there was not sufficient time for the presentation of all the papers. The attendance exceeded the expectations of those most interested. Among those present the largest numbers came from Colorado, Wyoming and Montana, but a number came from California, Nevada, Arizona, New Mexico, Washington, D. C., Boston, Mass., New York City, Philadelphia, West Virginia, Chicago, Missouri, Texas, Nebraska, Kansas, Oklahoma, and Tampico, Mexico.

President W. E. Wrather shared the responsibility of presiding with Max W. Ball, the vice-president, C. E. Decker, the secretary and Mrs. Ada E. Mastbrook had charge of registration and Dr. R. C. Moore, the editor took charge of manuscripts and records of the discussions.

At the first meeting Thursday morning greetings were extended by Hon. James T. Duce, Oil and Gas Inspector of Colorado, and by Mr. C. A. Fisher in behalf of the Rocky Mountain Association of Petroleum Geologists. To these greetings response was made by President W. E. Wrather.

While most of the papers dealt with the oil geology of the Rocky Mountain region, a number treated of the geology of California, Texas, Oklahoma, Kansas, Alberta, Canada and Roumania. One correction should be made in the program to the effect that paper Number 58 on Permo-Pennsylvanian Glaciation in the Wichita Mountains should be credited to Dr. S. Weidman.

Two highly respected members of the association died since the last meeting, Rollin D. Salisbury of the University of Chicago and G. H. Cox of the Josey Oil Company, formerly head of the Department of Geology at the Rolla School of Mines. The obituaries for these men were read by the secretary at the beginning of the Thursday afternoon session. The one for Professor Salisbury, our first honorary member, was written by President W. E. Wrather, and the one for Dr. Cox by V. H. McNutt.

Entertainment was provided for all visiting members of the convention Friday afternoon when the citizens of Denver furnished automobiles for a mountain trip of about sixty miles out southwest of Denver, first to the site of a well being drilled with a core drill, thence up through

the canyons and along the mountain sides to the top of Look Out Mountain, and back through the Mining School town of Golden.

Social features included a dinner Thursday evening for the members of Sigma Gamma Epsilon, the Geological, Mining and Metallurgical fraternity, arranged by Lambda Chapter of the Colorado School of Mines, at the Shirley-Savoy hotel.

The climax of the social features was reached at the association dinner Friday evening in the Magnolia Room of the Albany Hotel, at which about one hundred and thirty were present. The program was one of great originality. Max W. Ball served admirably as toastmaster and the toasts included "Stories of My Friend the Plainsman" by C. H. Wegemann; "How Old Was Nebuchadnezzar" and "How Old is Petroleum" by Rimrock Jones or Poison Spider, "The Interests of the Association" by W. E. Wrather; "The Making of a Pebble Pup" by E. F. Schramm; and "The Law Hound" and the "Rock Hound" by Wilfrid O'Leary. A number of original songs written for the occasion were interspersed with the toasts.

At the close of the meeting a group of the men started Saturday evening on a trip to the Salt Creek Field near Casper, Wyoming, but a terrible blizzard caught them on the way out from Casper, causing them to return to that city without reaching the field.

The executive committee of the association had several important sessions, and among other items of business decided, in response to an urgent invitation from Shreveport, Louisiana, to hold the next annual meeting of the association in that city March 22, 23 and 24, 1923.

The great success of the Denver meeting should be attributed first to the indefatigable and persistent efforts of Max W. Ball, to the able assistance of Charles M. Rath and Mrs. Ada Mastbrook, and to the fine co-operation of all the Rocky Mountain geologists, oil companies, and other organizations, and to the citizens of Denver in general.

CHARLES E. DECKER, Secretary.

REPORT OF THE RESOLUTIONS COMMITTEE

We, the members of the American Association of Petroleum Geologists, are deeply grateful to the people of Colorado and of Denver, for the welcome and the courteous hospitality extended to this Association on the occasion of this its semi-annual meeting. The Association is particularly indebted to the Denver Tourist Bureau for its active assistance in preparation for the meeting, the Albany Hotel for auditorium accommodations, and the individual citizens, whose generosity in furnishing transportation made possible the mountain trip.

The co-operation of the oil companies of the Rocky Mountain region is cordially appreciated for their financial contribution to expenses of the meeting, for their provision for the attendance of members of their geologic staffs, and for conveniences placed at our disposal.

The sincere thanks of the Association are expressed to the Rocky Mountain Association of Petroleum Geologists and their friends through-

out the Rocky Mountain region, whose whole-hearted contribution of time and effort have been so largely responsible for the success of this meeting.

Finally we extend our thanks to Max W. Ball, Charles M. Rath and Mrs. Ada M. Mastbrook for their ingenuity, industry and patience in the arrangements for and conduct of this meeting.

Respectfully submitted,

W. E. PRATT

K. C. HEALD

R. S. MCFARLAND

Resolutions Committee.

NOTICE TO MEMBERS

The vote on changes in the constitution submitted to the members of the association will be closed February 1, 1923. In case any members have votes which they still desire to turn in, they should be mailed as promptly as possible to the secretary, C. E. Decker, Norman, Oklahoma.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following applicants for membership in the Association. This publication does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to Charles E. Decker, Norman, Oklahoma.

(Names of sponsors are placed beneath the name of each applicant.)

FOR FULL MEMBERSHIP:

Tom J. Cullen, Casper, Wyoming.

Leon J. Pepperberg

R. E. Collom

T. E. Swigart

Charles J. Hares, Denver, Colorado.

Wallace E. Pratt

C. A. Fisher

Max W. Ball

J. Volney Lewis, New Brunswick, N. J.

Paul Weaver

D. R. Semmes

E. DeGolyer

Pierce Larkin, Tulsa, Oklahoma.

L. B. Snider

Sidney Powers

Charles T. Kirk.

James M. Douglas, Denver, Colorado.

Dean E. Winchester

Max W. Ball

Thomas T. Harrison

Roscoe E. Shutt, Mexico, D. F.

B. L. Laird
O. A. Cavins
R. C. Stoner

Barnabas Bryan, New York City.

Carl B. Anderson
Sidney Powers
A. F. Truex

Walter Krampert, Cheyenne, Wyoming.

Max W. Ball
Colin C. Rae
Harold T. Morley

Edward D. Lynton, Abilene, Texas.

Stephen H. Gester
Wm. S. W. Kew
E. M. Butterworth

Hugh A. Stewart, Denver, Colorado.

E. G. Sinclair
H. T. Morley
L. V. Fees

Nicholas L. Taliaferro, Berkeley, Calif.

G. C. Gester
S. H. Gester
Hugh B. Webster

John B. Whisenant, Duncan, Oklahoma.

Leon J. Pepperberg
W. E. Wrather
C. E. Decker

Robert V. Anderson, Menlo Park, California.

Max W. Ball
Dean E. Winchester
Charles T. Lupton

Karl H. Schilling, Bartlesville, Oklahoma.

Chas. C. Hoffman
Archie R. Kautz
T. K. Harnsberger

Henry V. Howe, Baton Rouge, Louisiana.

Ben K. Stroud
J. P. D. Hull
Clyde M. Bennett

Francis E. Vaughan, San Francisco, California.

F. B. Plummer
John R. Suman
W. F. Bowman

Joseph Jensen, Los Angeles, California.

Wayne Loel

Wm. S. W. Kew

Irving V. Augur

J. Claude Jones, Reno, Nevada.

Walter Stalder

C. Max Bauer

J. Elmer Thomas

Paul B. Whitney, Denver, Colorado.

Dean E. Winchester

Max W. Ball

Charles T. Lupton

Howard Clark, Utica, Ohio.

Frank Carney

George C. Matson

A. L. Beekly

Wilson B. Emery, Casper, Wyoming.

Clarence B. Osborne

Max W. Ball

T. T. Harrison

John B. Case, Los Angeles, California.

Wm. W. S. Kew

Irving V. Augur

R. E. Collom

FOR ASSOCIATE MEMBERSHIP:

Paul A. Schlosser, Laramie, Wyoming.

S. H. Knight

Eliot Blackwelder

John L. Rich

Clayton A. Moorson, Laramie, Wyoming.

S. H. Knight

Eliot Blackwelder

John L. Rich

William A. Burress, Tulsa, Oklahoma.

Sidney Powers

J. L. Gartner

Robert E. Garrett

William C. Kinkel, Tulsa, Oklahoma.

Burton Hartley

Sidney Powers

Robert C. Garrett

Ernest C. Moncrief, Arkansas City, Kansas.

J. V. Howell

F. L. Aurin

Glenn C. Clark

O. B. Wendeln, Pittsburgh, Pa.

Roswell H. Johnson

S. G. Huntley

R. E. Somers

Hugh L. Burchfiel, Berkeley, California.

Fred A. Davies

Jack M. Sickler

Irvine E. Stewart

Julian Q. Myers, Tulsa, Oklahoma.

Sidney Powers

George C. Matson

A. P. Wright

Frank T. Clark, Lexington, Kentucky.

H. E. Rothrock

E. Paul Rothrock

R. D. Reed

Charles R. Hoyle, Tulsa, Oklahoma.

S. Weidman

V. E. Monnett

O. F. Evans

Thomas B. Romine, Walla Walla, Washington.

L. R. Van Burgh

Walter A. English

J. M. Sickler

Gerald H. Westby, Denver, Colorado.

E. Eggleston Smith

Max W. Ball

R. Crandall

OBITUARY

ROLLIN D. SALISBURY

It is our sad duty to record the death of one of our most beloved and respected members, Dr. Rollin D. Salisbury, which took place in Chicago on August 15, 1922, as the result of a heart attack which overtook him



several months previously. Dr. Salisbury's death is peculiarly a loss to this Association, as almost ten percent of the total membership, exclusive of Associates, are graduates of the Department of Geology at the University of Chicago and therefore received their geological training under

his direction. Approximately one out of every three of the above men received Doctor's degrees in the department.

It is safe to say that each of our members who were his students feels a real personal bereavement in Dr. Salisbury's death. His passing marks to each the loss of a loyal friend and a competent adviser. His interest in his students continued beyond the termination of their college work and he followed the career of each with a fatherly concern. Their successes pleased him equally as much as though they were his own personal achievements. Without a family of his own, he reached out and bestowed on his favorite students the affection normally accorded to sons. He remarked to the writer shortly before his death that his greatest satisfaction in life lay in the ties of friendship and loyalty which bound such a large number of his former students to him.

Dr. Salisbury's chief interest lay in teaching and it is undoubtedly as a great teacher that he will be chiefly remembered. His original work in the field of geology was primarily concerned with studies of continental glaciation, prosecuted in his earlier years, and his more recent contributions were in the preparation of text books which are now standard throughout the colleges and universities of this country. During the last few months of his life he was engaged in a complete revision of the three-volume text book for advanced geological courses. At the time of his death, he was seriously contemplating taking advantage of his privilege of retirement, due at the end of another year of teaching, to prepare a volume designed to popularize the science of geology for the benefit of the layman; and he talked of yet another ambition to write a treatise on the climates of geological time. It is indeed a misfortune that one so eminently fitted for the task could not have lived to write these much needed books.

His methods of selecting students for his department were frequently unique. At the beginning of almost every school year he took a class of students for their beginning course in geology. Out of this class he usually selected a few individuals, whom he thought were qualified to make satisfactory geologists. He particularly delighted in making the course a perfect nightmare of rapid-fire questions for these select few, and if they stood up satisfactorily under the grilling, he took their breath away at the end of the Quarter with an invitation to dinner, during the course of which he encouraged them to continue with their work in geology. Thus students were occasionally, even frequently led to take up geology as a major subject when they had planned for themselves quite different careers. If personalities may be permitted here, the writer was thus early won away from an ambition to study law and was diverted to the field of geology.

Dr. Salisbury was a man of very positive character, of strong likes and dislikes. He positively could not tolerate an idler. If such a one inadvertently registered for his classes, he seldom received encouragement to continue beyond the first course. He ardently believed in the doctrine of hard work and religiously practiced it himself. This con-

tributed in no small degree to his untimely end. For the past few years his duties were so increased by the deanship of the Ogden Graduate School of science that his friends recognized he was overworking. Yet he persisted in carrying the entire burden of the administration of the department of geology and seldom delegated such duties to his assistants. His physician urgently insisted on his leading a less strenuous existence, but in spite of these warnings, he often worked in the library or in his



office at Rosenwald Hall until well past midnight. His health had not been robust for several years, and he was several times obliged to relinquish his teaching duties and resort to travel to recuperate.

He felt it his duty to remain at his post during part or all of the Summer Quarter, since at that time the student body of the University is composed largely of graduate students or teachers, and he was deeply interested in broadening the outlook of teachers on the science of geology. An interesting sidelight on his character was exhibited in his relations with these summer students, many of whom had returned to the University from teaching positions, to "brush up" on the natural sciences. He displayed a marvelous patience in answering their immature questions, and an unusual degree of courtesy, which was occasionally in

striking contrast to his petulance with younger students from whom he expected a greater degree of understanding.

To understand and fully appreciate the various angles of his character, it was necessary to know him for a period of years. To many who knew him casually, he remained a paradox. Because of his occasional gruff and abrupt manner, he earned for himself among undergraduates, the appellation of "the bear." But to those who succeeded in winning his approval, he was the most humane and kindly of men, although even to those whose friendship he prized most highly, he seemed at times unnecessarily gruff. When he threw off the duties of his office, he had the faculty of making himself the most agreeable and pleasant company, which fact was adequately attested by his great popularity at faculty and other social gatherings. His interest in and patience with children was one of his outstanding characteristics. Many a tiny youngster in the University community learned to wait expectantly, near the sidewalk for the pat on the shoulder and the few kindly words of greeting which inevitably came with his appearance. Surely there could be little meanness or narrowness in a character which could so readily win the approval and confidence of little children.

He was human, and being human, he had his frailties and short-comings, as all of us do. But now that he is gone, his true elements of greatness stand out in bold relief. The high regard in which he was generally held was evidenced at the funeral service by one of the most remarkable floral tributes ever witnessed at the University,—a huge bank of flowers from scientific societies, institutions of learning and individuals, which completely filled the end of Leon Mandel Hall. One wonders whether out of the developing generation, there will rise teachers of equal greatness. His death marks an irreparable loss to the University and to the teaching profession, a great personal loss to his host of friends, and he will surely survive in memory as one of the most effective and renowned geologists of the century.

W. E. WRATHER.

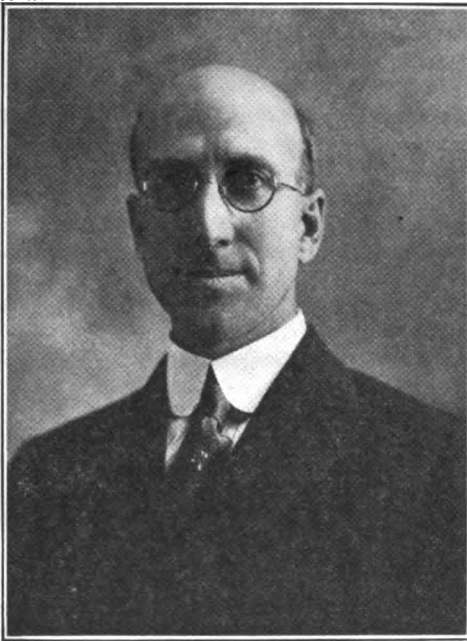
GUY HENRY COX

Dr. G. H. Cox, Chief Geologist for Josey Oil Company of Oklahoma City was fatally injured in an automobile accident on the night of August 19th and died without recovering consciousness at 3 A. M. August 20th.

When returning from work alone about eleven o'clock at night, evidently blinded by the bright lights on an approaching car, Dr. Cox drove over a steep embankment about a mile and a half north of Bristow, Oklahoma. His car, a Franklin, turned over and he was caught and crushed beneath the steering wheel. The accident was discovered by passersby practically as soon as it occurred and Dr. Cox was promptly removed to a hospital in Bristow and medical aid administered but death resulted from hemorrhage of the lungs at 3:00 A. M. Thus "passed on" one of the best known and most highly respected geologists.

Guy Henry Cox was born in the town of Lehigh, Webster County, Iowa, May 4th, 1881. His father Edward Henry Cox and mother Ada Wilson Cox were pioneer Iowa stock.

Guy Henry Cox attended public schools at Lehigh and later at Fort Dodge. After completing his public and High School education in 1901 at Fort Dodge he entered Northwestern University from which he graduated with B. S. degree in 1905. From 1905-1906 he was a gradu-



ate student in the School of Mines, University of California. It was during this training that Dr. Cox started an intensive study of mining geology. In 1906 he left California and entered the University of Wisconsin where he pursued his specialty, geology, and 1908 was a Fellow in Geology, under C. K. Leith and first started teaching in connection with his school work. Later he received a Ph.D. degree from Wisconsin University.

From the University of Wisconsin he returned to the University of California in 1908 where he remained until 1909 when he was called to fill the position of Assistant Professor of Mineralogy and Geology, Missouri School of Mines, Rolla, Mo. In 1911 Prof. Cox was made Head of De-

partment Geology, Missouri School of Mines which position he held until 1920.

Professor Cox was a man of high ideals and worked tirelessly to build up the department under him. That he was efficient as well as tireless is evidenced by the high rank the Geology department of Missouri School of Mines attained under his direction.

Dr. Cox was not content to be a highly successful teacher but had the rare quality of being able to combine the theoretical with the practical. Aside from his work as a teacher Dr. Cox under the firm name of Cox & Radcliffe established offices as Consulting Geologists in Tulsa, Oklahoma and also in Rolla, Missouri. In this work he personally directed geologic work in Oklahoma, Texas, Kansas, Arkansas and Louisiana. During 1920 Dr. Cox accepted a position as Chief Geologist, Josey Oil Company and spent practically his entire time in reconnaissance work having two or more detail parties constantly at work outlining areas favorable for oil production.

Dr Cox was also an author of note and contributed many valuable papers. Among them should be mentioned the following:

Copper in Southwestern Wisconsin. *Mining & Scientific Press* Vol. 99 No. 18 P. 529 - 1909.

Elizabeth Sheet of Lead and Zinc District of Northern Illinois. *Ill. State Geol. Survey, Bull.* 16 - 1909.

Lead and Zinc district of Northern Illinois, *Mining World.* Vol. 34 No. 8 - 1911.

Methods of Prospecting and Estimating ore bodies in the Wisconsin Zinc and Lead district. *Missouri School of Mines and Metallurgy—Thesis for E. M. degree* 1914, and

Geologic Criteria for determining the Structural Position of Sedimentary Beds. *Missouri School of Mines & Metallurgy—Technical Series* Vol. 2 No. 4 - 1916.

Dr. Cox's best work was his recent book prepared in collaboration with Professors Drake and Muilenberg of Missouri School of Mines entitled "Field Methods in Petroleum Geology." This book is the first in its field and contains a great many new and practical suggestions regarding the best practice in field examination of petroleum prospects.

Dr. Cox was an active members in the following technical societies:

American Institute of Mining & Metallurgical Engineers—1912.

American Association of Petroleum Geologists—1917.

Society for the Promotion of Engineering Education—1919.

The Geological Society of America—1920.

In addition to the above he was a Mason, and a member of Alpha Chi Sigma, (Chemical fraternity); Tau Beta Pi (Honorary Member); Beta. Mo. and Phi Kappa Phi (Charter Member) M. S. M. 1920. Being very active, a thorough students and constructive thinker, Dr. Cox crowded into his life of 41 years an experience superior to that of many older men in the same profession.

Professor Cox was married to Kittie May Gates at Clear Lake, Iowa

on December 27th, 1909 shortly after he became Assistant Professor of Geology & Mineralogy, Missouri School of Mines. To this union were born a boy, Kenneth Dale, July 30, 1912, and a girl, Catherine Gates, May 18, 1914. Mrs. Cox and both children survive Dr. Cox.

I was privileged to be the first Assistant to Professor Cox when he came to Missouri School of Mines and can never forget his genuine hospitality, kindly interest and never-tiring effort to help and inspire his subordinates.

I am sure that the American Association of Petroleum Geologists feels, with his many other friends that Guy Henry Cox has left a memory of which we may well be proud.

V. H. McNUTT.

AT HOME AND ABROAD

CHAS. R. FETTKE, Associate Professor of Geology and Mineralogy at Carnegie Institute of Technology, Pittsburgh, Pa., has completed an investigation of the oil resources of the coals and carbonaceous shales of Pennsylvania for the State Bureau of Topographic and Geological Survey.

PIERCE LARKIN, of Tulsa, has been working in Nebraska.

W. E. WRATHER presented the University of Chicago with a tract of land near St. Genevieve, Missouri, where an important stratigraphic section is exposed, for the use of the summer school in geology.

A. W. MCCOY located the Empire well in Sec. 31 T. 31 S., R. 7 E., Cowley Co., Kansas.

J. M. SANDS located the Phillips Petroleum Co. well in Sec. 1, T. 23 S., R. 4 E., Butler Co., Kansas.

D. E. WINCHESTER, Consulting Geologist of Denver, Colo., spent October in Oklahoma on professional work.

H. HARPER MCKEE, of New York City, spent November in Northern Louisiana.

W. C. THOMPSON, of the Sun Co., has been working at Smackover, Arkansas.

W. B. EMERY, of the Ohio Oil Co., returned to Denver in October after spending the summer in Montana.

W. B. WILSON, of the Gypsy Oil Co., Tulsa, returned to Tulsa in October from the Sweetgrass Arch, Montana.

L. E. KENNEDY, associated with R. B. WHITESIDE, has moved from Muskogee to Tulsa and is located in the Atlas Bldg.

CARL BEAL, of San Francisco, has been in Washington representing the oil producers of California in tax matters.

W. A. ENGLISH, of Los Angeles, is associated with the Standard Oil Co. of California and spent the summer in Montana.

R. VAN A. MILLS, of the Bureau of Mines, studied the faults of Salt Creek and Teapot Dome in October and November.

THE STANDARD OIL Co. of California has invaded Texas under the name The California Co., and E. D. Lynton is in charge of the work at Abilene, Texas.

C. A. HARTNAGEL, Assistant State Geologist of New York, is preparing a bulletin on restoring pressure in the oil sands of western New York.

H. F. CROOKS is working in northern Africa.

S. A. JUDSON, of Tulsa, is working in northern Texas.

L. E. ENGLISH is associated with Foster & Reiter.

L. G. KEPPLER is Chief Geologist of the Southwestern Petroleum Co., of Tulsa.

W. E. WRATHER returned to 6044 Bryan Parkway, Dallas, in September.

A. O. HAYES is working for the Standard Oil Co. of N. J. at Comodoro Rivadavia, Argentina.

F. B. PLUMMER is agent for the Dutch Shell at Houston.

W. L. GOLDSTON and LEON RUSS represent the U. S. Tex. Oil Co. in Texas.

J. M. SANDS is in charge of the land department of the Phillips Pet. Co. at Bartlesville.

DEAN STACEY, of Oklahoma City, has been in Denver on professional business.

C. P. BERKEY is examining the oil possibilities of Mongolia.

J. E. ELLIOTT and F. C. MERRITT published a paper, "Core drilling in oil fields of Southern California," in *Summary of Operations, California Oils Fields*, for July.

VICTOR E. GOTHE, of the Pure Oil Co., recently returned from Columbus to Caracas, Venezuela.

MEMBER LIST

OF AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

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Adams, G. Whitney, Camden, Arkansas.
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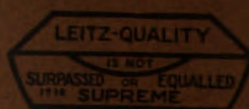
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